Prioritising carbon reduction in UK public sector Flood and Coastal Risk Management

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PhD Thesis

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Contents

ORGANISATION PERMISSION

A letter requesting permission

Bolton University
Dean Road
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BL3 5AB

04/10/2018

Jo Jolly
Environment Agency
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Newtown Industrial Estate
Northway Lane
Tewkesbury
Gloustershire
GL208JG

Dear Jo

I am undertaking an action research study in to how I can improve the prioritisation of low carbon in UK Public Sector FCRM construction. I would be grateful if you would grant permission for my research to proceed.

Two copies of the letter are enclosed. Please sign and date both. Keep one copy for your files and return one copy to me.

Katherine Ibbotson 04/10/18

I hereby give permission for Katherine Ibbotson to undertake her research in Environment Agency.

Jolly

Signed .... Dated ....

ABSTRACT

The UK construction industry has seen an overall increase in CO_2 levels from 1990 to 2017 (Statista, 2020), with UK public sector Flood and Coastal Risk Management (FCRM) having contributed to this increase. The establishment and development of organisational systems and culture is well documented within current literature, along with the influence it can have upon the embedding of new initiatives. The UK construction industry has demonstrated little progress on embedding low carbon practices. This study investigates the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). The research adopts a main survey and action research activities as its research strategy within a UK public sector FCRM organisation. The survey was undertaken within a leading government organisation, where its role in implementing, prioritising and promoting low carbon is investigated and a number of action research activities have been undertaken to improve practice, with the outputs from the WLCPT utilised for analysis.

The main objectives of this study (survey) investigated whether demography of participants (OB1); organisational change (OB2); organisational leadership (OB3); quality of training (OB4) and organisational culture (OB5) influences low carbon prioritisation. The action research objectives of this study investigated whether cost (OB6), quality of implementation of a WLCPT (OB7) and type of training (OB8) influence tonne of carbon and whether low carbon promotion influences organisational culture (OB9). The key findings infer, null hypotheses cannot be rejected, there is no relationship for OB1, OB3, OB6, OB7 and OB8. For OB2, OB4, OB5 and OB9, the null hypotheses are rejected; there is a relationship between the variables within this study.

This research study has made an original contribution to knowledge, through 'research in action' how a WLCPT can be implemented within a client construction organisation and its supply chain; how continuous improvement can be undertaken; what works, what doesn't and the reasons why. This key contribution builds upon limited information currently available on how to implement low carbon initiatives and tools, providing an insight on how to make the implementation of a WLCPT more efficient, building on knowledge by promoting and sharing a common message. The action of implementation to build up knowledge, is through the contribution to publicly available information in terms of a WLCPT, training, case studies and factsheet. Along with a 'collaborative democratic partnership' with the organisation and its

supply chain is evidenced; how they were part of the cyclical process outlined; how they engaged with the choice of research and the knowledge, becoming part of the knowledge solution. Through the 'sequence of events', approach, trial and error and review to problem solving in a complex adaptive organisation, the maturity of the organisation on the journey is not only about evidence through outputs, but practical steps to implementation with learning outcomes.

This thesis reflects the changing nature of low carbon solutions within UK public sector FCRM construction and the role the author has played in its development. It offers an understanding of challenges in implementing new systems and processes within an organisation and its supply chain, and is directly related to wider learning across industry. The processes of thinking, acting and making sense of author's work, the narration of the processes and the changes that have taken place in author's actions, show how low carbon knowledge can support a Complex Adaptive System (CAS), providing practical evidence to support complexity theory; this utilises continued improvement loops of positive and negative feedback that is always being reformulated, reworked and continually improved upon, in order to achieve the aim of the study.

The gaps and imitations within this study challenge the thesis findings, whereby the process of quality of implementation of WLCPT and type of training are diminished due to the consistency in governance and compliance at both project and contract level. The action research outputs also challenge the results for OB6 whereby the unit 'tonne of carbon' does not influence cost. The basis of the test is the utilisation of the organisation's cost data and outputs from the WLCPT, where the initial and final cost and carbon data is analysed. The initial cost estimate is primarily based on initial budget allocation and not a defined or formal cost estimate, therefore the results identify no relationship. However, evidence from the WLCPT supporting documents, utilised for knowledge sharing and training, identify through case studies a clear correlation that low carbon does leads to low cost and therefore a relationship is identified.

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ACKNOWLEDGEMENTS

This research would never have been possible without the initial support and kind assistance extended to me by many individuals and organisations. I wish to thank my supervisor, Dr. Peter Farrell, for his patience, encouragement, support and guidance extended to me throughout my PhD journey.

My particular appreciation also goes to the Environment Agency for their initial support and willingness to accept a significant change within organisation initiated by my concerns and drive to make a positive change. The Flood and Coastal Risk Management (FCRM) Steering Group, Sustainable Business colleagues, wider Project and Contract Management department and Environment Agency supply chain are acknowledged gratefully for their contribution and support. I'm also especially thankful to Sally Sudworth and Lynda Guest for their friendship and moral support throughout my PhD journey and through my role as Carbon Planning Manager. I would also like to thank Ian Corder and Brian Francis for affording me the freedom to make the Carbon Planning Manager role my own, indulging every opportunity identified to promote Eric (WLCPT) to anyone willing to listen.

I am also thankful to all the respondents who completed the survey and devoted many hours of their valuable time in picking up new processes and systems, and taking the time to learn and discuss low carbon as an integral part of their business as usual approach, and providing me with the required information to test my hypotheses. I also wish to thank all the academics and practitioners who have reviewed and provided feedback on my journal, conference publications and presentations and for their contribution towards shaping this research. To each and every individual, and organisation that contributed in whatever way in making this research study a reality, thank you.

Finally, I wish to express my appreciation to all my family, for their continued understanding, support and encouragement throughout this study. With special thanks go to my husband, David and my children Avery and Aubrey for being the reason for making this change.

ABOUT THE AUTHOR

As a Chartered Environmentalist with the Chartered Institution of Water and Environment Management (CIWEM), the author has a solid belief that environmental issues are important and felt the need to improve practices. The author was formerly a Commercial Services Manager within a leading government organisation involved in UK public sector FCRM construction works, managing national cost management frameworks to ensure value for money and service was provided; she recognised that at the time there was a disconnect between her values and the role. This was alongside the legislative Climate Change Act 2008 and central Government's promotion of the Infrastructure Carbon Review (ICR) report (HM Treasury, 2013) which stated that by reducing carbon, it is possible to reduce costs and improve efficiency. As an experienced project manager, I found carbon and cost links were not evident at the project level; there were tools for both carbon and cost systems but the facilitation of a link between the two components was not readily available. Whilst cost was fully embedded into project processes, carbon was not and it was used primarily as a reporting function. The author envisioned a different approach, to better understand the increased climate change challenges presented on a day-to-day basis within an organisation that focuses heavily on the implementation of UK public sector FCRM construction projects.

During this study the following conference and journal papers have been published:

Ibbotson, K. and Farrell, P. (2019). The challenges of prioritising low carbon in public sector Flood and Coastal Erosion Risk Management (FCERM) construction. *International Journal of Building Pathology and Adaptation*. Vol. 37 No. 5, pp. 615-628.

Ibbotson, K. and Farrell, P. (2019). How training can support low carbon prioritisation in flood and coast risk management construction. *IPGRC 2019.* Salford: Salford University;

- Achieved Energy House Lab Award;

Ibbotson, K. and Farrell, P. (2017). Change management in public agencies to attain efficiencies. *IPGRC 2017.* Salford: Salford University.

- Achieved Dean of Research Award;

Ibbotson, K. and Farrell, P. (2015). Change management in public agencies to attain low carbon efficiencies. *IPGRC 2015.* Salford: Salford University

DECLARATIONS

The work contained within this thesis, except where indicated by specific reference, is the result of the candidate's own investigation and the views expressed are those of the candidate.

No portion of the work presented within this thesis has been submitted for any other degree or award at this or any other university or place of learning, nor is being submitted concurrently in candidature for any degree or other award.

ABBREVIATIONS

AACM	Alkali-activated cementitious material
BIM	Building Information Modelling
BIS	Business Innovation and Skills
CAMC3	Creating Asset Management Capabilities phase 3
CapEx	Capital Expenditure
CAS	Complex Adaptive Systems
CAW	Carbon Accounting Workbook
CC	Carbon Calculator
CCL	Cost and Carbon Lead
CCS	Carbon Capture and Storage
CCT	Cost and Carbon Tool
CDU	Collaborative Delivery Unit
CDM	Construction, Design and Management Regulations 2015
CE	Conformite Europiene/European Conformity
CEO	Chief Executive Officer
CFC	Chlorofluorocarbons
CIWEM	Chartered Institute of Water and Environment Management
CMT	Carbon Modelling Tool
CO_2	Carbon Dioxide
COP	Conference of the Parties
COR	Carbon Optimisation Report
DEFRA	Department Environment, Fisheries and Rural Affairs
EA	Environment Agency
Eric	Eric Whole life carbon planning tool
FBC	Full Business Case
FCR	Final Carbon Report
FCRM	Flood and Coastal Risk Management
GHG	Green House Gas
H	Hypothesis
i3P	Infrastructure Industry Innovation Partnership
ICE	Institution of Civil Engineers
ICR	Infrastructure Carbon Review
IEM	Internal Environment Management

I-MR	Individual – Moving Range
IPA	Infrastructure Projects Authority
IPCC	Intergovernmental Panel on Climate Change
IPGRC	International Post-graduate Research Conference
ISO	International Organisation for Standardisation
IT	Information Technology
KPI	Key Performance Indicator
LCF	Low Carbon Future
Lite	Lite version of Whole Life Carbon Planning tool
MEICA	Mechanical Electrical Instrumentation Control Automation
MP	Member Parliament
MWF	Minor Works Framework
NASA	National Aeronautics and Space Administration
NCPMS	National Capital Programme Management Service
NEAS	National Environmental Assessment Service
NFM	Natural Flood Management
NGSA	Next Generation Supplier Arrangements
OB	Objective
OBC	Outline Business Case
OFWAT	Office of water services
OI	Operational Instruction
OPC	Ordinary Portland Cement
OpEx	Operational Expenditure
PAS	Publicly Available Standard
PAR	Participatory Action Research
PCT	Project Cost Tool
PDU	Project Delivery Unit
PR09	Price Review 2009
PVc	Present Value Cost
Q	Quarter
RAG	Red, Amber, Green
RICS	Royal Institution of Chartered Surveyors
RFS	Readiness for Service
RO	Research objective

RQ	Research question
SOC	Strategic Outline Case
SUDS	Sustainable urban drainage systems
t CO_2	Tonne of Carbon Dioxide
UK	United Kingdom
UKWIR	United Kingdom Water Industry Research
UN	United Nations
UNCC	United Nations Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
VAR	Variable
WEM	Water Environment Management
WLCPT	Whole Life Carbon Planning Tool
WWNP	Working with Natural Processes
4D/5D	4/5 Dimensional

DEFINITIONS

- Capital carbon, or 'CapCarb', refers to emissions associated with the creation of an asset. Capital carbon is being adopted within the infrastructure sector because it accords with the concept of capital cost. (Going forward, the related term 'embodied carbon' will continue to be used at a product-level, whereas capital carbon will have greater relevance at an asset-level) (HM Treasury, 2013);
- Demolition carbon, carbon associated with the demolition of life-expired asset/sub-assets. Three categories are assessed:
  - Material waste – transportation off-site of demolished materials;
  - People – travel to/from site;
  - Plant – transportation to/from site and fuel use;
  - Carbon associated with the final disposal of waste is not included within the calculator (EA, 2018c).
- Gateway stages (OGC, 2007):
  - Gateway 1 – Business justification;
  - Gateway 2 – Delivery strategy;
  - Gateway 3 – Investment decision;
  - Gateway 4 - Readiness for service;
- Operational carbon, or 'OpCarb', describes emissions associated with the operation and maintenance of an asset. It is analogous to operational cost and is quantified in t CO_2e/year (HM Treasury, 2013). Four subcategories are assessed within WLCPT (EA, 2018c):
  - Use – use/operation of assets, based on travel to/from the site;
  - Maintenance – planned maintenance activities, based on an assessment of travel to/from the site and use of plant and materials where required;
  - Repair – an assessment of unplanned repair activities, based on an assessment of travel to/from the site and use of plant and materials where required;
  - Energy – power consumption;
- Refurbishment carbon, carbon associated with interventions at the end of the asset/sub-asset's useful life that extend the useful life (EA, 2018c);
- Replacement carbon, carbon associated with re-building an asset/sub-asset at the end of it's useful (or if refurbished, extended useful) life (EA, 2018c);

- Residual carbon, the carbon emissions associated with assets that extend beyond the 100-year project lifespan. The residual carbon is presented and subtracted from the whole life carbon total to produce a total net emissions figure for the project (EA, 2018c);
- Sequestration: carbon sequestration is the prevention of greenhouse gas build-up in the earth’s atmosphere by methods such as planting trees to absorb carbon dioxide (Collins, 2020);
- Whole life carbon combines both capital and operational carbon and is analogous to whole life cost (HM Treasury, 2013).

CHAPTER 1: INTRODUCTION

1.1 Background and rationale

There is great impetus to implement change in the UK economy but with the distraction of an economy that has been in recession and public sector staff subject to pay restrictions (The Guardian, 2018), trying to put change into practice becomes a challenging task. The difficulties of implementing change however, are not specific to the here and now. The UK construction industry has had many attempts to move to a more 'lean' and innovative approach, highlighting the need for the industry as a whole to improve (Latham 1994, Egan, 1998, Wolstenholme, 2009, Farmer, 2016, HM Government 2013a, 2017a, 2018b, 2019a, ICE, 2009, 2011, 2020). UK Governments 25-year action plan (2018a) clearly highlights the need for change: 'Down the centuries, we have shaped and adapted our rural and urban landscape to suit our purpose, not always aware of the lasting effects of our actions – for good or ill – on the appearance and health of the environment. The scale of human impact on the planet has never been greater than it is now'. The need for industry to change has been further exacerbated, with the increasing emphasis and social awareness around climate change and need to reduce green-house gases (GHGs), an area that has been known and predicted by scientists was early as 1824 when Joseph Fourier described what we known as the greenhouse effect (Wogan, 2013). The first prediction of the earth warming due to increased carbon dioxide (CO_2) levels in 1896 was by Svante Arrhenius, who was the first to quantify the contribution of CO_2 to the greenhouse effect and to speculate about whether variations in the atmospheric concentration of carbon dioxide have contributed to long-term variations in climate. The conclusion was that doubling CO_2 levels would trigger a rise of about 5-6C (The Guardian, 2005). The question then is why have previous attempts at implementing low carbon solutions and the change this requires within the construction industry been received with enthusiasm but limited in their effect? At the time of writing his report, Wolstenholme (2009) stated that the success of such initiatives in the context of UK construction industry in the period 2004 – 2007, has fallen short: 'there has been some progress but nowhere near enough', with the industry for the last decade being 'sheltered by a strong economy. This has enabled construction to prosper without having to strive for innovation' or improve systems and processes. Whether an economy is thriving or in recession, so far progress hasn't been sufficient. Therefore it could be challenged that the necessary impetus for carbon reduction as a driver to protect the planet is also dependant on the state of urgency that an individual, group or organisation may 'feel' as part of their cultu*re and drivers. 'Encoded in our language is the understanding that disasters tend to expose that which was previously hidden. As the planetary crisis unfolds as a series of emergencies, our decisions will reveal who we are' (Safaran Foer, 2019).*

'Today's economic climate is different and offers an opportunity to think again' (GLA Economics 2008 cited in Sundar, 2013). In order to address the underlying issue of whether the construction industry and the public sector will be successful in implementing the net zero government initiative, further understanding of organisational culture and change is required along with its role within a complex system. The public sector has a long-established way of working and culturally ingrained practices have often appeared to be a barrier to implementing change. The democratic leadership approach often results in discussions with unions or employees before organisational change occurs. This can result in longer timescales for implementation and reducing the sense of urgency needed to gain support for change initiatives. Employees in both public and private sectors of construction need to buy-in to the process for change, in order for this to be successful; and the process for change needs to be linked to organisational culture. Understanding whether public sector construction is (or is not) different from private sector construction, is dependent on individual organisations and the 'complex interrelations between organisational culture and organisational climate' (Mehmet, 2006).

A literature review has been undertaken focusing on the implementation of government initiatives within the construction industry. There is a need to measure the effect of organisational culture on change implementation and the need for clear leadership in organisations to implement and sustain change within the industry through knowledge share and training. The challenge for public sector organisations and their supply chains is to ensure that government priorities such as a low carbon economy, increased efficiency, the progress of Building Information Modelling (BIM) 4D and 5D, alongside the wider agenda of the digital economy and the 4th industrial revolution (World Economic Forum, 2019) are fully understood, embedded and prioritised on public sector construction schemes. This is in addition to the demand for construction schemes to be built on time, to the required engineering and environmental quality and cost, whilst also meeting the needs of partnership funding bodies and stakeholders. All of these requirements do not cohesively work together and often result in conflicting priorities, relying on public sector organisations and their supply chains to collaborate in order to achieve targets set by government.

The construction industry has been affected by many government initiatives focused on improvement; whether these changes focus on the need for driving productivity and improvements, improved leadership, focus on the customer, integrated processes, quality driven agendas and commitment to people and a clear route-map for change (Latham, 1994, Egan, 1998, Farmer 2016, HM Government, 2009, 2011a, 2011c, 2013a, 2013b, 2017a, 2017b, 2018a, 2018b). The 'Never Waste a Good Crisis' report (Wolstenholme, 2009) stated that changes have not been wide ranging or self-evident due to the lack of incentives created by a buoyant economy, and it is only since the 2008 recession (Allen, 2019) and Brexit challenge within the UK that organisations are having to make cutbacks and demonstrate that they are not only adding value to the work they do, but leading the way with green technology and low carbon initiatives. Moving to a low carbon economy is the right thing to do, for our economy, our society and for future generations (HM Government, 2011a). This sentiment is supported by the UK Low Carbon Transition Plan (HM Government, 2009), which clearly outlines the implications of a low carbon economy and its effect on the construction industry; however, all of this is dependent on the construction industry operating at its best (HM Government, 2009). This is supported by the Industrial Strategy (HM Government, 2017a) which states: 'Our long-term goals are to make clean technologies cost less than high carbon alternatives, and for UK businesses to take the lead in supplying them to global markets.'

Demonstration of how the UK construction economy is pursuing a low carbon agenda to date, is arguably somewhat lack lustre, despite UK Government setting clear targets. This view is supported by Thornley-Walker (2010) who states that engineers have been given clear advice on their duty through (i) The Institution of Civil Engineers in its 2009 State of the Nation report (ICE, 2009) which recommended that carbon should become a 'key aspect' of all design, and (ii) The Engineering Council (UK) in 2009, which issued its document 'Guidance on Sustainability' (Engineering Council, 2009), stating that engineers should: (a) undertake a comprehensive risk assessment before a project begins, (b) ensure that the risk assessment includes the potential environmental, economic and social impacts, beyond the lifetime of the engineering project or product, (c) recognise the potential long-term aspects of risk, and (d) give sustainability the benefit of the doubt, adopting a precautionary approach where scientific knowledge is not conclusive. This call for improvement is echoed in State of the Nation 2020 report (ICE, 2020a), with Keith Howells ICE vice president stating, ‘we should be thinking about how to use this once-in-a-generation opportunity to recalibrate and reassess the economy and how we do things – not least, how we build, deliver and maintain the infrastructure we will need in the future’ (Howells, 2020).

Under the Construction, Design and Management Regulations (CDM) (HSE, 2007 cited in Thornley-Walker, 2010), all those involved in construction have ‘a duty either to design-out dangers, or to reduce risks to acceptable levels’; this view is supported by current CDM regulations (HSE, 2015) and the former Department of Business Innovation and Skills (BIS, 2010a) who state that design can make an impact of reducing CO_2 through in-use emissions. However, very few members of construction design teams feel compelled, or justified, to cut down or design-out and replace high-carbon materials on the above advice or to meet government requirements (HM Government, 2005; cited in Thornley-Walker, 2010). The Innovation and Growth Group recognise that government needs to drive change and innovation amongst the construction community and has stated that ‘this will involve both push (e.g. legislation) and pull (e.g. incentives to create a market). It will require a definite long-term plan allowing business to adapt and plan ahead to deliver infrastructure and buildings required for the UK to meet its low carbon targets in the long-term. Without their backing and support there will not be the impetus to move forward and work towards a low carbon society. This in turn will aid in trying to change the perception of the general populous’ (Bryne, et al. 2010). Such plans are progressing with the recognition that the Infrastructure Carbon Review (ICR) has established how increased resource efficiency and a reduced carbon footprint can facilitate reduced cost, both upfront and during the whole-life of the built asset’ (IPA, 2016).

1.2 Justification of the research

Low carbon solutions in infrastructure have been well documented and promoted in most areas of the UK. The Clean Growth Strategy (HM Government, 2017b) provided £2.5 billion investment in low carbon innovation, focusing on ‘emissions from business and the public sector falling by 30%, through the improvements in energy efficiency, reducing energy use per unit of output as well as reducing the carbon content of industrial energy use, through switching to cleaner fuels, improving business energy efficiency and standards for commercial buildings, and agreeing tighter targets to reduce central government emissions’. Although Flood and Coastal Risk Management (FCRM) as a specific asset management function sits within the infrastructure sector, it is led primarily by public sector organisations. For organisations such as the Environment Agency (EA), improvements and carbon reduction focus has been primarily on operational carbon that derives from operation and maintenance, and is measured via energy use and transport. Capital carbon usage in constructing FCRM assets has had less focus historically. The capital carbon reduction target for FCRM within the UK EA between 2005 and 2015, was 10% between the stages of project appraisal and the end of construction.

As the capital element of construction works within public sector agencies is predominantly undertaken by external suppliers, it is not just public sector organisations themselves but their supply chains that need to be influenced. In 2016 the EA Trucost report (EA, 2016a) stated that: 'For GHG emissions, the top ten suppliers (within the top 97 suppliers) contribute 67% to the total environmental cost in the EA supply chain. Those companies operate primarily in construction. Their high contributions are driven by intensive operations as well as a high expenditure'. There is a need to understand the drivers and vision of private organisations and the conditions that they operate in, to design and implement incentives and change within their value chains. As many public organisations operate under specific framework agreements, set criteria are outlined at tender stage, including visions and aspirations of what clients' needs are to be achieved on construction schemes, in collaboration with appointed supply chain. The alignment of client and supplier requirements and ambitions are essential if there is to be improvement in the implementation of UK Government initiatives (Farmer, 2016). Such visions and aspirations however, lead to economic competitiveness, which may be defined as the ability to maintain or expand market position based on cost structures (Sathre, 2007). It follows that due to the culture of the construction industry, after initial and basic requirements are met, the cheapest construction solutions are most often utilised. Sustainable targets inclusive of carbon are often 'soft', with no specific financial or reputational pain or gain. This diminishes the level of focus and prioritisation that reducing carbon has in comparison to reducing cost. This argument is supported by Ng (2012) who stated that 'the importance of public sector clients driving and providing incentives for the use of low carbon dioxide materials in the construction industry' is the only way to see effective improvement. Similarly, the requirement to include carbon emissions in risk assessments has not been emphasized and climate change has been specifically excluded from the UK National Risk Register (HM Government, 2011b) on the grounds that it would not affect the safety and security of the UK within a five-year time scale (Thornley-Walker, 2010).

The use of carbon calculators, a tool which enables capital or whole life carbon to be measured, recorded and reported on, are used on some public sector construction schemes. The calculators enable project teams to demonstrate that they have achieved savings on carbon output from appraisal, through to detailed design and construction end. Carbon information is monitored within the public sector, and should be a key target for all organisations. According to Thornley-Walker (2010), utilising the correct incentives or pressures, through the use of selection criteria and enhanced effort within the design and procurement processes, could affect changes in weeks that most members of society would hardly achieve in years. However, the current likely outcome is still that cheaper cost is prioritised over low carbon solutions, resulting in low carbon targets being missed. This is likely to be due to the level of understanding by professionals, and pressure to prioritise tangible cost savings over less tangible low carbon solutions. It is notable that when Paul Morrell came to the newly created post of UK Government Chief Construction Advisor in November 2009, he stated *'we're going to need to start counting carbon as rigorously as we count money and accepting that a building is not of value if the pound signs look okay, but the carbon count does not'* (Richardson, 2009). Organisations such as SWECO (SWECO Urban Insights, 2020), Skanska (Skanska, 2020) and Anglian Water (Anglian water, 2020) have all focused on the alignment of cost and carbon, all at differing levels and granularity with the attempt to highlight and evidence the benefit of focusing on both carbon and cost. However, this is as yet not consistently or routinely undertaken across UK Industry.

In comparison the government's efficiency initiative tasked public sector organisations to provide year-on-year efficiency savings on their construction schemes. 'An efficiency saving is a monetary saving which has been incurred by undertaking works in a different way or with a different resource, but still achieving either the same output or a greater standard' (EA, 2011). Baselined in 2010, the government's 20% efficiency target resulted in many quick wins with project teams recording reduced travel and increased use of teleconference and videoconferencing as an efficiency saving. Going forward the efficiency target has become more challenging with project teams having to innovate to find alternative solutions to demonstrate actual savings. No longer are these only reviewed at detailed design or construction stage but project teams are being encouraged to identify potential efficiency savings at project start, with contract targets and project budgets being set on the basis of project savings being achieved.

This iterative process is also relevant to carbon reduction whereby, the process for quick wins needs to be passed and more focused thinking on early reporting and identification of savings to government, so acts as a driver to motivate teams to achieve savings identified (HM Government, 2010). However, for some, the basic identification of savings whether in the context of efficiency, cost or carbon reduction requires a change in mind-set and motivation, along with the recognition and requirement to take a 'whole systems approach' to decarbonisation (HM Government, 2011a), to ensure that the innovative use of alternative technology and approach to construction solutions is progressed.

1.3 Aim and objectives

1.3.1 Research aim

The study will investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). Through the process and activities undertaken as part of the WLCPT implementation, a suitable context for a shift in practice will be tested. The WLCPT is also referred to as 'Eric' within the organisation and public domain, for the purpose of this thesis 'Eric' will be referred to as WLCPT, further details are provided in Chapter 6. The main objectives for this study are as follows:

- OB1: To investigate whether demography of professionals influences low carbon prioritisation;
- OB2: To investigate whether organisational change influences low carbon prioritisation;
- OB3: To investigate whether organisational carbon leadership influences low carbon prioritisation;
- OB4: To investigate whether quality of training influences low carbon prioritisation;
- OB5: To investigate whether organisational culture influences low carbon prioritisation;
- OB6: To investigate whether tonne of carbon influences cost;
- OB7: To investigate whether the quality of implementation of a whole life carbon planning tool (WLCPT) influences tonne of carbon;
- OB8: To investigate whether type of training influences tonne of carbon;

- OB9: To investigate whether low carbon promotion influences organisational culture.

1.3.2 Outline methodology

Following a critical review of the literature, the author has established: the research problem; the aim of the study; the objectives and has developed the initial conceptual framework. Each stage is further refined based on a survey carried out of practicing UK public sector FCRM construction professionals. This enables the author to further investigate 'How do I improve what I am doing?' in order to improve the learning of others through action research activities (McNiff, 2011). Through an Action Research approach, an empirical research method has been adopted.

1.3.3 Research questions, objectives, hypotheses and variables

In consideration of the above methodology and in the context of low carbon in UK public sector FCRM construction, the main survey will be utilised to test a number of variables. Table 1.1 provides research questions (RQ), objectives (OB), hypotheses (H) and variables (VAR). Each VAR is aligned to survey questions or Action Research outputs. Table 1.2 provides the survey and action research data utilised to test the thesis VARs. The hypotheses in this thesis are written as the alternative hypotheses, although it is recognized that statistical testing is undertaken against the null. The evolution and background of the objectives, hypotheses and variables can be found in section 4.3.

Table 1.1 Research question, objective, Hypotheses, Variables and Unit of measure

	A	B	C	D	E
1	Research Question (RQ)	Objective (OB)	Hypothesis (H)	Variables (VAR) and Unit of measure (UofM)	
2	RQ1: Does demography of professional influence low carbon prioritisation?	OB1: To investigate whether demography of professionals influences low carbon prioritisation	H1: The demography of professionals influences low carbon prioritisation	VAR 1 demography of professionals, UofM sector, gender, age, experience and role.	VAR 2 low carbon prioritisation, UofM 0 - 100%
3	RQ2: Does organisational change influence low carbon prioritisation?	OB2: To investigate whether organisational change influences low carbon prioritisation	H2: The level of organisational change influences low carbon prioritisation	VAR 3 organisational change, UofM 0 - 100%	
4	RQ3: Does organisational carbon leadership influence low carbon prioritisation?	OB3: To investigate whether organisational carbon leadership influences low carbon prioritisation	H3: The level of organisational carbon leadership influences low carbon prioritisation	VAR 4 organisational carbon leadership, UofM 0 - 100%	
5	RQ4: Does quality of training influence low carbon prioritisation?	OB4: To investigate whether quality of training influences low carbon prioritisation	H4: The quality of training influences low carbon prioritisation	VAR 5 quality of training, UofM 0 - 100%	
6	RQ5: Does organisational culture influence low carbon prioritisation?	OB5: To investigate whether organisational culture influences low carbon prioritisation	H5: The level of organisational culture influence low carbon prioritisation	VAR 6 organisational culture, UofM 0 - 100%	
7	RQ6: Does tonne of carbon influence cost?	OB6: To investigate whether tonne of carbon influences cost	H6: The tonne of carbon influences cost	VAR 8 tonne of carbon, UofM unit tonne of carbon	VAR 7 cost, UofM pound sterling (£)
8	RQ7: Does the quality of implementation of a whole life carbon planning tool influence tonne of carbon?	OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influences tonne of carbon	H7: The level of implementation the quality of implementation of a whole life carbon planning tool influence tonne of carbon	VAR 9 quality of implementation of a whole life carbon planning tool, UofM 0 - 100%	VAR 8 tonne of carbon, UofM unit tonne of carbon
9	RQ8: Does type of training influence tonne of carbon	OB8: To investigate whether type of training influences tonne of carbon	H8: The type of training influences tonne of carbon	VAR 10 type of training, UofM 0 - 100%	
10	RQ9: Does low carbon promotion influence organisational culture?	OB9: To investigate whether low carbon promotion influences organisational culture.	H9: The level of low carbon promotion influences organisational culture	VAR 11 low carbon promotion, UofM 0 - 100%	VAR 6 organisational culture, UofM 0 - 100%

Table 1.2 Method, VAR and data utilised

Model	Variables (VAR)	Data utilised to test VAR
Main Survey	VAR 1 demography of professional	Questions 1 to 5
Main Survey	VAR 2 low carbon prioritisation	Questions 11 to 13
Main Survey	VAR 3 organisational change	Questions 16 to 20
Main Survey	VAR 4 organisational carbon leadership	Question 9 and 21
Main Survey	VAR 5 quality of training	Question 15
Main Survey	VAR 6 organisational culture	Questions 6 to 8 and 10
Action Research		Capital Carbon Maturity Review
Main Survey	VAR 7 cost	Question 14 and 22
Action Research		AR data whereby projects that have both a cost and carbon submission at the end of the project
Action Research	VAR 8 tonne of carbon	WLCPT carbon outputs
Action Research	VAR 9 quality of implementation of a whole life carbon planning tool	WLCPT carbon outputs and quarterly reports
Action Research	VAR 10 type of training	Number of project managers who have completed the Eric e-learning module; submitted a carbon return at the end of the project and applied low carbon best practice approaches.
Action Research	VAR 11 low carbon promotion	Wider awareness raising and publicising activities undertaken by the research practitioner and assessment of the organisations' capital carbon journey and alignment to Publicly Available Specification (PAS) 2080 (BSI, 2016).

1.3.4 Research focus

From researching current thinking and processes and how they influence the progression of low carbon decisions, it is apparent that government initiatives are heavily focused on infrastructure (HM Government, 2010). It was felt that focusing this research within the FCRM function of UK construction gives the opportunity to progress research in this specific construction sector. The low carbon government initiative is aimed at public sector construction, embedding new ways of working into the DNA of current processes and procedures (HM Treasury, 2013). The establishment and development of organisational systems and culture is well documented within current literature, as are current Environment Management Systems, for example the 'ISO 14000 family of standards reflects international consensus on good environmental and business practice' (ISO Central Secretariat, 2009).

A view of the status of organisational culture will be undertaken via a survey, focusing on the author's current understanding of low carbon and how organisational culture has influenced the prioritisation of low carbon within their organisations. From researching information on how low carbon is being promoted and prioritised and the relationship to cost, it has highlighted the limited available information, from a UK public sector FCRM construction perspective. This research will reduce the gap in current academic literature whilst progressing a whole life carbon planning tool (WLCPT) to improve the monitoring of 'whole life' carbon and the relationship with cost on UK public sector FCRM construction schemes, which will support the promotion of low carbon solutions through project life cycles.

The aim of the Infrastructure Carbon Review (ICR) report (HM Treasury, 2013) is to realise the value of low carbon solutions and to make 'carbon reduction part of the DNA of infrastructure in the UK'. It also starts to address low carbon aspirations set out in the UK Government's Construction Industry Strategy – one year on report (Cabinet Office, 2012). The report identified links between reductions in carbon and reductions in costs and it proposed strategies to bring both carbon and cost down simultaneously when constructing, operating and maintaining infrastructure. It noted it would require a broad range of stakeholder involvement in managing and creating infrastructure assets as the 'value chain' (Cabinet Office, 2012). All parts of the value chain are partially reliant on others to enable low carbon solutions, but clients play the pivotal role in providing organisational carbon leadership and removing blockers. They also stand to benefit the most from doing so. Overarching recommendations are that UK Government and industry clients should work together to make carbon reduction a requirement on all of their infrastructure projects and programmes initially by 2016 and is further set out within the UK Government Construction Strategy 2016 – 2020 (IPA 2016). Within the ICR (HM Treasury, 2013) specific recommendations included: effective leadership; metrics and governance and innovation and standards. PAS 2080: 2016 (BSI, 2016) is a specification that has been established to clarify these areas further and is supported by certification to aid organisations in reducing their greenhouse gas emissions associated with the infrastructure industry. The standard aims to achieve a systematic process across industry regardless of role or organisation (BSI, 2019).

Understanding current barriers to the promotion and prioritisation of government initiatives are key to ensuring that any future changes to processes and procedures are fully accepted and embedded. There is evidence that the promotion and success of previous initiatives (Wolstenholme, 2009, HM Government, 2009, 2011a, 2011c, 2013a, 2013b, 2017a, 2017b) have been limited, due to factors such as lack of leadership, organisational culture and limited incentives for suppliers and clients to promote low carbon when the economic climate is buoyant. UK Government since the Egan report has focused on continued improvement within construction, whether it is improving efficiency, carbon capture and storage (CCS) or BIM. The enthusiasm to 'push or pull' the UK construction industry into a more data driven and perhaps more efficient level of service to rival manufacturing has been on the horizon (HMSO, 1944; HMSO, 1962; HMSO, 1964; Latham, 1994; Egan, 1998; HMSO, 2011; Vernikos, 2013). However, despite positive UK Government commitment to reducing climate change, the construction industry has been slow to change with only slices of the building and infrastructure industry actively tackling carbon reduction and implementing changes.

UK Government is continually under pressure to reduce public spending on national services' The need to change the way services work with less staff and available resources whilst still achieving the highest of standards. The necessary targets to ensure public and environmental safety, UK Government argues that 'reducing carbon reduces cost' (HM Treasury, 2013). However, there is limited information in regards to this cost saving within FCRM schemes. Historically, for public sector project delivery (EA specific), low carbon data has been provided at appraisal (Gateway 1), design (Gateway 2) and construction (Gateway 4) stage with 10% reduction target calculated from project appraisal stage to construction finish. This measure does not clearly prioritise low carbon at the appraisal phase, nor does it offer any incentives to project teams to actively promote low carbon solutions. In addition to this approach, the promotion of efficiency savings can have a detrimental effect on low carbon solutions due to current procurement methods and limited understanding of the true cost of low carbon options within FCRM. At present, there is data available to quantify that low carbon solutions reduce costs; this is focused on the construction work undertaken by water companies such as Anglian Water (HM Treasury, 2013), who have evidenced that implementing low carbon solutions has a direct correlation to project costs. This approach is not consistent across the construction industry, where evidence to substantiate these savings are less transparent or available.

The majority of current low carbon reporting and monitoring in FCRM is reliant on capital carbon generated and not operational carbon (EA, 2014b). The change in focus to a whole life approach will support current low carbon reporting in other sectors (HM Treasury, 2013). It will also support current research on embedded and carbon off-setting (HM Government, 2013a). However, a review of operational carbon may result in greater oversight of current operational processes, whether this is resulting in a reduction of resource or a tighter control of current practices. It is this perception and barrier to accepting low carbon and the monitoring of current solutions that will need clear and effective leadership and a strategy to implement any future changes within UK construction. The research will look to investigate the OBs outlined in Table 1.1

1.4 Research theory

This research study has touched upon many possible research theories from: change management; organisational culture; leadership; behavioural change; improvement; motivation; management; transitional; incremental; living theory; systems and complexity. In order to investigate whether the prioritisation of low carbon solutions influences organisational culture, in the context of UK public sector FCRM construction, through the implementation and development of a WLCPT, a theory which encompasses these areas which is interdisciplinary, addresses uncertainty and non-linearity is required. 'Theories indicate the strength of relationship and direction' (Farrell et al. 2017). Complexity theory emphasises uncertainty and feedback loops that support and enable change to systems or organisations (Park, 2017). Complexity theory will be taken forward within this study, the reasons for this are presented below.

According to Holland (2014) complex systems exhibit a distinct property called '*emergence'*, roughly described as '*the action of the whole is more than the sum of action of the parts'*, within large government organisations, the overall direction needs to be taken into account rather than the singular action of a department, team or project. Complexity theory focuses on how parts at a local level (micro) can influence behaviours and changes within a system and the overall outcome at a global or national level (macro) (Osifo et al., 2011, McElroy, 2000, McKenzie et al., 2004). This allows for activities to be undertaken to encourage the empowerment of suppliers and staff to drive forward initiatives at a local level whilst still operating within a wider organisational framework or boundaries. Incorporated within complexity theory are four main theories; self-organisation theory, non-linear theory, network theory and complex adaptive systems (CAS). CAS absorb information from their environment, creating knowledge that can aid action within their own CAS, alongside learning and innovation with these systems (Mason, 2007, Fioretti et al., 2004). Non-linear systems are described as processes of change with feedback loops, such as the butterfly effect and chaos theory, where behaviour is determined by its adaptive parts interaction, which are diverse in form and ability. CAS arises 'from the collective control that the parts exert on the whole' (Osifo et al., 2011, Price, 2014, Foster, 2005, Sherif, 2006 and Meek, et al., 2007).

1.5 Research method

This research study analysed primary and secondary data, via a literature review, questionnaire and the action research study of a leading government organisation and its role in implementing, prioritising and promoting low carbon. Using qualitative analysis from a survey, the data sought to provide a datum of current organisational culture in UK public sector FCRM construction and the current prioritisation of low carbon solutions. The survey was undertaken at the start of the study period. The action research tasks span a timescale from 2014 to 2020 and involve the implementation and development of a WLCPT (EA, 2016b). The activities undertaken supporting the implementation of the WLCPT along with supporting document and outputs will be utilised for OB6, OB7 and OB8, along with the use of the EA's Project Cost Tool (PCT) (EA, 2015a). OB9 utilises the author's Capital Carbon Maturity Review (EA, 2019g), undertaken on behalf of the organisation, alongside the activities undertaken by the author to publicly validate and promote low carbon within the organisation, its supply chain and across wider industry. Quantitative and qualitative results will be reviewed, the findings discussed, analysed and evaluated. The conclusions summarise the findings and results, and provide recommendations for future research.

The baseline survey was sent out to FCRM practitioners, to investigate the organisational culture at the start of the implementation of the WLCPT and evidencing OB1; OB2; OB3; OB4 and OB5. The EA's WLCPT and PCT was utilised to test potential cost savings through the prioritisation of low carbon within UK public sector FCRM construction projects. The scope for updating the organisations current carbon calculator is to facilitate a link between carbon and cost, supporting the capability of readily identifying carbon hotspots and their alignment to cost where practicable (Victoria and Perera, 2018). The proposal for the WLCPT will be progressed and the funding sought. The wider promotion of low carbon through the author's professional role will be utilised to test how low carbon promotion influences organisational culture, OB9. The assessment of the carbon maturity journey that the organisation will take will be used as qualitative evidence. The 'data will be brought together and sorted systematically' coded and summarised in tables that can be analysed and themes progressed. The results have been presented and followed by findings stemming from the results (Farrell, 2011).

1.6 Contribution to knowledge

Contribution to knowledge is evidenced through the following areas:

- Research in action
- A collaborative democratic partnership
- A sequence of events and approach to problem solving

Research in action is via the resolution of important social and organisational issues together with those who experience these issues directly. How a WLCPT can be implemented within a client construction organisation and its supply chain; how continuous improvement can be undertaken; what works, what doesn't and the reasons why. This key contribution builds upon limited information currently available on how to implement low carbon initiatives and tools, providing an insight on how to make the implementation of a WLCPT more efficient, building on knowledge by promoting and sharing a common message. Both for an individual researcher (author) perspective and that of a government organisation, leading in low carbon. The action of implementation to build up knowledge, is through the contribution to publicly available information. A collaborative democratic partnership with the organisation and its supply chain is evidenced; how they were part of the cyclical process outlined; how they engaged with the choice of research and the knowledge, becoming part of the knowledge solution. Through the sequence of events and approach to problem solving, the approach, trial and error, review to problem solving in a complex adaptive organisation. The maturity of the organisation on the journey contribution is not only about evidence the outputs and practical steps to implementation with learning outcomes.

Research methods included the survey at the start of the implementation of the WLCPT. The testing of whether low carbon prioritisation lead to lower cost was undertaken as part of the tool development utilising current and historic local government project data. The implementation of WLCPT and the level of embedding and inclusion into the organisation was used to test whether low carbon could influence an organisational cultural change. The WLCPT was utilised on UK public sector FCRM construction works by internal staff and the external supply chain.

This research study has made an original contribution to knowledge, through research in action; a collaborative democratic partnership and through evidencing a sequence of events and approach to problem solving, by investigating the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). It has expanded the knowledge base around complexity theory and action research, and evidenced how the consideration of low carbon can be practically improved: through the implementation and development of a WLCPT, supported by: documentation; training; reporting; awareness raising; communications and wider promotion and prioritisation at project, organisation and industry level. The research supports this evidence-based approach and attempts to influence organisations within UK public sector FCRM construction and current thinking. The key study aim was to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). This is intended to provide a suitable evidential context for paradigm shifts in practice, and act as the catalyst for increasing the success of low carbon initiatives and cost reduction in the UK construction industry.

1.7 Structure of the thesis

1.1 Chapter 1: Introduction

Chapter 1 introduces the research providing a brief summary of the background to the research, research justification, aim and objectives, research focus, method adopted, contribution to knowledge and organisation of the thesis.

2.1 Chapter 2: Literature review

Chapter 2 presents the detailed literature review of the study. It provides details on the UK's current commitments, literature that addresses the issues relating to low carbon, climate change and the need for low carbon solutions within construction, the role of leading government organisations and their supply chain. Organisational culture is examined in respect to low carbon commitments for a leading UK public sector FCRM organisation and its supply chain; along with the current commitment to low carbon by UK infrastructure as a whole.

3.1 Chapter 3: Initial conceptual framework

Chapter 3 presents the initial conceptual framework of the research highlighting key areas identified from literature.

4.1 Chapter 4: Research Methodology

Chapter 4 provides the research methodological design and the process adopted for conducting the research. It outlines the process for establishing the research problem presenting, in detail, the research philosophy, approaches, strategies, choices of methods, time horizons and techniques and procedures.

5.1 Chapter 5: Updated conceptual framework

Chapter 5 presents the updated conceptual framework of the research highlighting action research key concepts identified from literature and survey and how this translates to the action research method actions.

6.1 Chapter 6: Research method – action research

Chapter 6 presents the action research spiral (Research Methodology, 2018) for two key action research activities. It follows the continued improvement review from the implementation of a WLCPT and the wider promotion of low carbon across industry.

7.1 Chapter 7: Data analysis of survey

Chapter 7 analyses the empirical evidence gathered from the survey undertaken. It provides the background information and the process adopted for the survey followed by a detailed analysis.

8.1 Chapter 8: Data analysis of action research

Chapter 8 presents the analysis of the evidence gathered from the implementation of a WLCPT. It provides the background information, the process adopted for action research activities followed by a detailed analysis.

9.1 Chapter 9: Findings and discussion

Chapter 9 provides an overview of the main research findings while comparing and contrasting the findings from the survey and action research implementation, with the literature findings.

10.1 Chapter 10: Conclusions and recommendations

Chapter 10 concludes the research, providing the implications of the research to the theory and practice, research limitations and future research areas.

1.8 Summary and link

This chapter outlines the research discussed in this thesis by introducing the background of the research, within the context of UK public sector FCRM construction. It also presents a justification for the research for carbon reduction with the aim to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT) and to evidence the achievement of the following objectives:

- OB1: To investigate whether demography of professionals influences low carbon prioritisation;
- OB2: To investigate whether organisational change influences low carbon prioritisation;
- OB3: To investigate whether organisational carbon leadership influences low carbon prioritisation;
- OB4: To investigate whether quality of training influences low carbon prioritisation;
- OB5: To investigate whether organisational culture influences low carbon prioritisation;
- OB6: To investigate whether tonne of carbon influences cost;
- OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influence tonne of carbon;
- OB8: To investigate whether type of training influences tonne of carbon;
- OB9: To investigate whether low carbon promotion influences organisational culture.

Through an initial study questionnaire and the implementation of a WLCPT, the contribution to knowledge by investigating the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). Expanding information available, utilising evidence-based data, to influence organisational culture within UK public sector FCRM construction and the wider industry. The aim was to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT); the study method was via a survey and action research approach. The next chapter presents the literature synthesis for the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The previous chapter provided an introduction to the research presented in this thesis. This chapter intends to provide a detailed literature synthesis on the key research areas pertaining to this study. Accordingly, the chapter includes:

- an overview of climate change and its effects while bringing in various climate change statistics and literature on the definitions and vulnerabilities in the context of carbon;
- the position of UK Government and its commitment to carbon reduction and its implications;
- the UK public sector and specifically Flood and Coastal Risk Management (FCRM) construction works;
- the chapter provides the literature findings on organisational culture and the influence of leadership to effect change;
- an introduction to publicly available carbon tools and a synthesis on how standards can play a part in effecting low carbon change within organisations;
- a review of literature is presented on how promotion and implementation of low carbon solutions can lead to reduced costs;
- a synthesis is provided on how implementation of low carbon solutions and initiatives can enable UK Government to achieve its commitments and effect change across the industry. It appraises the role public sector organisations have in ensuring successful implementation.

2.2 Climate change and its effects

2.2.1 International agreements

'Climate change is one of the few scientific theories that makes us examine the whole basis of modern society. It is a challenge that has politicians arguing, sets nations against each other, queries individual lifestyle choices, and ultimately asks questions about humanity's relationship with the rest of the planet' (Maslin, 2014). Climate change is already with us, as recognised by the global community and United Nations Climate Change (UNCC) Conference of Parties (COP) 25 Madrid (UNCC, 2019). It is the greatest emerging humanitarian challenge of our time; the effects of changing weather patterns and more extreme climate events can be seen around the world (Henderson, 2009; IPCC, 2018). Most climate scientists agree the main cause of the current global warming trend is human expansion of the 'greenhouse effect' (NASA, 2017). It is recognised by the United Nations, through its establishment of the United Nations Framework Convention on Climate Change (UNFCCC). It was acknowledged that there was a problem, but with little scientific evidence of the effects of climate change in 1994, the UNFCCC looked to the Montreal Protocol of 1987: 'it bound member states to act in the interests of human safety even in the face of scientific uncertainty'. The Convention set an ambitious but specific goal 'to stabilize greenhouse gas concentrations, at a level that would prevent dangerous anthropogenic (human induced) interference within the climate system' stating that 'such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner'. The protocol focused on developing countries leading the way, as they had been the source of the majority of greenhouse gas (GHG) emissions.

Internationally binding emission reduction targets were set out within the Kyoto Protocol and were implemented from February 2005. This was a heavier burden on developed nations under the principle of 'common but differentiated responsibilities' (UNFCCC, 2018a). The Paris Agreement brings all nations to a common cause to combat climate change and adapting to its effects. The main aim of the Paris Agreement is focused on 'strengthening global response to the threat of climate change, by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit temperature increases further to 1.5 degrees Celsius' (UNFCCC, 2018b). All parties are required to regularly report on their carbon emissions and their efforts at achieving reductions. The UNFCCC will take a global stocktake every 5 years (UNFCCC, 2018b). However, the effect of the United States of America (USA) withdrawing from the Paris Agreement was described by Professor Stephen Hawking as 'catastrophic', stating that President Trump's decision would cause 'avoidable environmental damage to our beautiful planet, endangering the natural world, for us and our children' (BBC, 2017a).

2.2.2 Greenhouse gas (GHG)

When discussing the GHG effect, it is the inclusion of: Water vapour; Carbon dioxide (CO_2); Methane; Nitros oxide and Chlorofluorocarbons (CFC's). Global warming leads to a wide range of melting snow and ice, and leads to global rising sea levels, as the largest emission and the most significant effects of climate, carbon dioxide gasses have been called the main GHG (Li, 2012). NASA (2017) highlights CO_2 is 'a minor but very important component of the atmosphere, CO_2 is released through natural processes such as respiration and volcano eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels. This is the most important long-lived 'forcing' of climate change'. According to the Carbon Fund, the CO_2 increase is having a dramatic impact, on both warming the climate and altering weather with more droughts and more very extreme weather events, with climate change being man-made (Carbon Fund, 2013). The effect of human activity is supported by the American Geophysical Union (AGU, 2017) who state that 'at the global level, atmospheric concentrations of CO_2 and other heat-trapping GHGs have increased sharply since the Industrial Revolution. Fossil fuel burning dominates this increase. Human-caused increases in GHGs are responsible for most of the observed global average surface warming of roughly 0.8°C (1.5°F) over the past 140 years. Because natural processes cannot quickly remove some of these gases (notably CO_2) from the atmosphere, our past, present, and future emissions will influence the climate system for millennia'. With GHG having increased due to economic and population growth, atmospheric concentrations of CO_2, methane and nitrous oxide are unprecedented in at least the last 800,000 years (HM Government, 2014a).

The UNFCCC has since 1997 focused on the how collectively countries can 'consider what they could do to limit average global temperature increases and the resulting climate change' (Harvey, 2012). With the EU as a whole achieving the first phase of emission reductions (5% reduction in emissions by 2012 based on 1990 figures) and the UK's 'emissions fell by 36 million tonnes of carbon dioxide in 2011, a 6% drop' (Harvey, 2012). Clarke (2012) reported in The Guardian that the 'emissions for the rest of the world have increased sharply', and as such the emerging economies when viewed on an individual country level, with Europe only reducing their emissions by 1% (from 1990 to 2008) and the developing countries increasing their emissions by 7% in the same period, blurring the reported success of the Kyoto target (Clarke, 2012).

However, understanding the effects of GHGs and their effects on the atmosphere are according to NASA (2017) difficult to predict but certain outcomes and effects are likely; these are namely:

- On average, Earth will become warmer. Some regions may welcome warmer temperatures, but others may not;
- Warmer conditions will probably lead to more evaporation and precipitation overall, but individual regions will vary, some becoming wetter and others dryer;
- A stronger greenhouse effect will warm the oceans and partially melt glaciers and other ice, increasing sea level. Ocean water also will expand if it warms, contributing further to sea level rise;
- Meanwhile, some crops and other plants may respond favourably to increased atmospheric CO_2, growing more vigorously and using water more efficiently. At the same time, higher temperatures and shifting climate patterns may change the areas where crops grow best and affect the makeup of natural plant communities.

According to the Intergovernmental Panel on Climate Change (IPCC) in 2016, there is more than a 95% probability that human activities over the past 50 years have warmed our planet (cited in NASA, 2017). The American Geological Society (2017) advocate that cuts to CO_2 emissions will be needed to reduce the magnitude of climate change, this is in addition to preparing for changes that are now unavoidable and pursuing research to understand climate change. This must be by 'working with stakeholders to identify relevant information, and conveying understanding clearly and accurately, both to decision makers and to the general public'. Henderson (2009) supports this view in that effective delivery on climate change will require comprehensive and integrated action on mitigation and adaptation. This is especially since the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 (IPCC, 2019). Climate change is a long-term issue, and substantial mitigation requires a lasting effort involving complex interactions between environmental, economic, political, social and technological processes (Sathre, 2007). The GHG protocol (2019) sets the standard to measure and manage emissions and utilises Scopes 1, 2 and 3 to encourage companies, organisations, countries and cities to focus on rapid carbon reduction.

2.3 UK Government and its commitment to carbon reduction

The UK is the only country to have legislated to reduce its GHG emissions through the Climate Change Act 2008. The Act sets a target reduction for the built environment of net zero by 2050 compared to 1990. In 2011, UK Government (2011) stated in its Low Carbon Construction Action Plan that 'Climate change is one of the greatest threats facing the world today. There is an overwhelming scientific consensus that climate change is happening, and that it is primarily the result of human activity'. This view was supported by Chartered Institute of Water Environmental Management (CIWEM) in 2013, then Executive Director Mr Nick Reeves stated: *'Britain must do all it can to secure a fairer, sustainable and resilient future and eradicate poverty. Without action and investment, now, the devastating impacts of climate change will be widely felt by humankind leading to an escalating threat to biodiversity, agriculture, human health, water resources and energy supply. We need demonstrable commitment across the whole of civil society if we are to meet and adapt to a changing climate and if our communities are to become resilient to future climate shocks'* (The Environment Magazine May 2013). Yet despite this awareness raising and clear central government views, progress is slow, as evidenced six years later by Lesley Griffiths Wales Secretary of State for the Environment responding to the question (CIWEM, 2019): *'The Welsh Assembly voted ahead of Westminster to declare a Climate Emergency. What does this mean for Welsh Government Policy? It is a way to make people aware that climate issues really are an emergency – that we have 12 years to turn this around. It's critical to galvanise people to action. Whether this changes our policy or the work we're doing will depend on the advisory bodies such as the Committee on Climate Change (CCC) tell us. But we hope the declarations will trigger a wave of action from Welsh businesses, communities and individuals'.*

In order to deliver on the Climate Change Act 2008 target, the UK Government set a series of periodic carbon budgets. The fifth carbon budget set in June 2016, provided a target of reducing carbon emissions by 50% by 2030 compared to 1990 levels. Through the duration of this study, this target has changed and as of June 2019, the current target is now net zero by 2050 compared to 1990 levels. More recently the UK has ratified the Paris Agreement of 2015, which went further still and recommended that there is a global aim for being carbon neutral. The Paris Agreement provides a framework for governments as well as business and investors to keep global warming well below 2°C, pursuing efforts to limit the temperature increase to 1.5°C (HM Government, 2016). Nick Hurd MP, then Minister of State for Climate Change and Industry, negotiated for the UK and promoted British business at the 22nd UN climate change Conference of the Parties (COP 22) in Marrakesh; stated: '*The UK is ratifying the historic Paris Agreement so that we can help to accelerate global action on climate change and deliver on our commitments to create a safer, more prosperous future for us all*' (HM Government, 2016). '*COP 22 in Marrakesh is an important milestone which marks the shift from aspiration to implementation. We are going to use this positive momentum to grow the UK low-carbon sector, which is already worth over £46 billion, as we continue to provide secure, affordable and clean energy to our families and businesses*' (HM Government, 2016).

However, at the recent COP 25 in Madrid, progress on setting rules for international co-operation and carbon markets, transparency and common timeframes, were not successfully progressed with UN Secretary General António Guterres stating he was 'disappointed' with the results of COP 25 and that 'the international community lost an important opportunity to show increased ambition on mitigation, adaptation & finance to tackle the climate crisis' (Carbon Brief, 2019)

UK Government targets have changed in response to growing evidence and expert advice from bodies such as the Intergovernmental Panel for Climate Change (IPCC) and the Climate Change Committee (CCC). The policy paper Greening Government Commitments 2014 (HM Government, 2014b) sets a target of a 25% reduction of CO_2 emissions by 2020 compared to 2009/10. This target was re-published in 2016 which gave a 32% reduction by 2020, an additional reduction of 7%. The Green Government Commitment policy paper (HM Government, 2018b) was updated in July 2018 and the Government target to reduce carbon emissions was increased to 43%, this meant another 11%, by 2020 compared to the 2009/10 baseline. The target reduction in GHG emissions has grown from 25% to 43% and this applies to direct carbon. Each government department is required to make a contribution and for DEFRA this has increased from 38% to 44% reduction by 2020; this equates to 26,534 tonnes of CO_2 emissions. Leading government organisations such as the EA have been reporting on organisation corporate carbon emissions since 2006/07 and achieved 43% reduction in 2017. Comments on the IPCC report 2018 (BBC, 2018) stated that: It's the final call, say scientists, the most extensive warning yet on the risks of rising global temperatures. Its dramatic report on keeping that rise under 1.5 ^{o}C says the world is now completely off-track, heading instead towards 3 ^{o}C. Keeping to the preferred target of 1.5 ^{o}C above pre-industrial levels will mean 'rapid, far-reaching and unprecedented changes in all aspects of society'. It will be hugely expensive – but the window of opportunity remains open. These changes relate to the original target set in the Climate Change Act 2008 by the UK Government increasing its target still further to 57% reduction by 2030 compared to 1990 levels.

However, despite UK Government commitment to carbon reduction, challenges have been raised by Greta Thunberg, 2019 the Time Magazine's 'person of the year' (The Guardian, 2019a) and school girl climate activist, who since September 2018 has been staging a school strike to raise awareness of climate change has created a global movement of school strikers. During a presentation to UK parliament she challenged the UK Government in their decision making where it had not been the best interest of evidencing and promoting carbon reduction. Greta's statement of *'mind-blowing historical carbon debt and the UK's claims of world-leading progress on cutting emissions, being the result of 'creative accounting'*; whilst also highlighting the UK's, exploitation of fossil fuels; expansion of its North Sea oil and gas fields; airports and approval of a new coal mine in Cumbria; were challenged as being *'beyond absurd'* (The Guardian, 2019b).

This challenge was shortly followed by specific action from UK Government and local authorities. On 1st May 2019 , UK Government declared a climate emergency (BBC, 2019), by 12 June 2019 the then Prime Minister Theresa May made a legal change to the Climate Change Act 2008 committing Parliament to a net zero emissions target (HM Government, 2019a). EA Chief Executive Sir James Bevan then also showed support through this speech to Aldersgate group on 25th June 2019 stating: *'success in any organisation comes down to following a simple principle, which is this: The main thing is to make sure that the Main Thing really is the main thing. I'll be honest: I've been Chief Executive of the Environment Agency for over three and a half years now, and it's taken me a while realise what the Main Thing is. And the answer, which I now say to myself every day, is this: it's the climate emergency, stupid. That's because the biggest single threat to everything we all care about, and the biggest threat to everything the Environment Agency exists to do – protect people from flood and drought, enhance the environment, support sustainable growth – is climate change'*, (HM Government, 2019b).

As of 31st July 2019 205 of 408 local authorities had declared a climate emergency with many declaring a 2030 deadline 20 years ahead of the government's 2050 target, the Climate Emergency Network is claiming it to be the fastest moving environmental movement in recent history (Whitehead, 2019).

2.3.1 UK Government and industry

With all of these UK commitments there is a key need for UK Government and industry to work towards greater shared knowledge with other countries and become more unified in their approach to reducing emissions. The challenges facing the UK economy, environment and public health have been laid out in the UK Government's latest Climate Change Risk Assessment (HM Government, 2017c), which outlines ongoing commitment to ensure the country can adapt to a changing climate, and will be followed by the second National Adaptation Programme setting out how the government will be addressing these risks (HM Government, 2017c).

In 2011, the Carbon Plan (HM Government, 2011c) stated that the 'UK, in common with other countries, faces two great risks over the coming decades':

- 'First, if we are not able to constrain GHG emissions, the world faces the prospect of dangerous climate change, which will have unprecedented impacts on global security and prosperity;
- 'Second, the UK faces challenges to its energy security as our current generation of power stations closes and we must ensure supplies of energy which are resilient to volatile fossil fuel prices'.

It is recognised that the UK is not alone in acting on energy efficiency. Japan has set a goal of improving its energy consumption efficiency from 2003 levels by at least 30% in 2030. The Swedish Government has proposed an energy efficiency target to reduce energy by 20% between 2008 and 2020 (HM Government, 2011c). Although the UK contribution is small compared to China or USA, it is still important to the UK Government to be seen as a leader in low carbon change.

Government and industry working together is also a key UK based requirement, led by the Green Construction Board. Initiatives such as developing market and technology-based plans, are being progressed to drive carbon out of the built environment. It is however questionable as to the level of success these will have with a UK construction industry not fully committed to reducing carbon (Farmer, 2016). The low carbon route map developed by the Green Construction Board is a visual tool enabling stakeholders to understand the policies, actions and key decision points required to achieve the UK Government target of former 80% reduction in GHG emissions vs 1990 levels by 2050 in the built environment. Covering both buildings and infrastructure it addresses segments of operational and capital (embodied) carbon emissions (HM Government, 2013b). Embodied carbon emissions are associated with initial construction of an asset, along with those from asset maintenance and renewal. When combining these with operational emissions in terms of use, maintenance, repair and energy use a whole life calculation can be undertaken. Considering whole life carbon ensures that solutions with lower embodied carbon do not involve more energy and carbon intensive operations which offset the savings made in construction (Chisholm, 2013). The Green Construction Board also promotes that every company/project should set its own target and has undertaken works to support the construction industry as follows (Construction Leadership Council, 2019):

- The Green Construction Board has a sub-group that is addressing greening the industry that is focused on reducing carbon emissions during the construction phase of a project;
- A series of assessments have been carried out to consider the carbon emissions from construction in the UK based on a 2008 baseline.
- A series of 'how to' guides are available including 'how to reduce CO_2 on construction sites', 'how to save money and CO_2 through reducing business travel' and 'how to save money and CO_2 emissions through effective logistics'.

According to the Construction Leadership Council (2019) in order to achieve a net zero reduction by 2050 carbon emissions from the built environment industry needs to *'Act on Carbon: by setting carbon targets to design for low carbon, and to cut carbon everywhere for planned longevity'*. In addition to this, advice from the Green Construction Board includes: 'considering the energy requirements of projects deploying right size generators; specifying energy-efficient plant and procuring low carbon site accommodation' (Construction Leadership Council, 2019). All of these are considered to be indirect carbon emissions for organisations such as the EA, as they are associated with how supply chains manage the operation of construction overheads.

A construction industry target was set as part of the government Sustainable Construction Strategy 'As major construction clients, government departments must demonstrate clear leadership in the areas of whole-life cost and whole-life carbon. The Construction 2025 industrial strategy targets a 50% reduction in GHG emissions in the built environment' (IPA, 2016, HM Government 2019c). The ICR (HM Treasury, 2013) was commissioned by the Treasury to track performance against the targets and to set out in this strategy to make carbon reduction part of the DNA of infrastructure development in the UK. It also starts to address low carbon aspirations set out in the government's Construction 2025 Strategy (HM Government, 2013a). ICR (HM Treasury, 2013) identified links between reductions in carbon and reductions in costs, and proposes strategies to bring both carbon and cost down simultaneously when constructing, operating and maintaining infrastructure. When identifying the broad range of stakeholders involved in managing and creating infrastructure assets these are described as the 'value chain'. All parts of the value chain are partially reliant on others to enable low carbon solutions, but clients play the pivotal role in providing organisational leadership and removing blockers (HM Government, 2013a). Whereas similar initiatives have been run to control cost, successful implementation has been more apparent, with collaboration between stakeholders reducing construction costs by 15 to 20% through the use of items such as project bank accounts, modern procurement methods and efficiency saving reporting (Cabinet Office, 2012).

However, government and industry bodies are not just sitting back and waiting to be told what to do. The UK Water Industry Research (UKWIR) Chief Executive Officer Steve Kaye in a recent UKWIR publication highlighted carbon as one of the big questions facing the water industry, where Theme 4 – Global Challenges 'Making a positive contribution to a greener and more sustainable future' highlighted question 10 (UKWIR, 2019):

- How do we remove more carbon than we emit by 2050?
    - Establish where and how we can store energy;
    - Optimise energy generation and address energy waste;
    - Seek out novel materials to use in construction and rehabilitation with low embodied carbon.

Wales has also launched its detailed plans in March 2019 on how to cut its GHG emissions by 2050, setting out 100 priorities and policies that span government departments and the specialist research department at Cardiff University (Welsh Government, 2019). Scotland has also committed to becoming net zero by 2045, with the ambition to 'reduce emissions by 75%

by 2030, the toughest statutory target by any country in the world going above and beyond what the IPCC, has stated is required world-wide to limit warming by 1.5 degrees' (Scottish Government, 2019).

2.4 UK Construction and its commitment to carbon reduction

In the UK, many people are now having to cope with far more extreme weather conditions, with winter rainfall having consistently risen in England and Wales since records began in 1766. Over the past 45 years, the amount of rainfall in any period has also become heavier, with increased flooding forcing people from their homes and causing huge amounts of damage to property and infrastructure (Henderson, 2009). According to Meteorological office (2019) in February 2019, the UK experienced its fifth winter storm of the year, followed by exceptionally high temperatures. On '26 February a maximum temperature of 21.2 °C was recorded at Kew Gardens (London), the UK's highest temperature on record for a winter month' (Met Office, 2019). There is widespread awareness of carbon emissions within the water industry, extending to both operational and embodied emissions. Chisholm (2013) states that the extent of the ambition to reduce carbon is growing with water companies aspiring to carbon neutrality by 2050, delivered through a combination of energy efficiency, renewable energy generation and purchase of low-carbon grid electricity. This does not involve a large technological leap forward in order to achieve the kind of carbon savings proposed. Utilising a wide range of existing and developing technologies and commitment to carbon reduction whatever assets are subject to maintenance or replacement, have the potential to achieve reductions.

It is recognised that there are numerous potential options for reducing emissions and enhancing carbon sinks for GHGs, including actions within the building supply sector, and forestry sector (Sathre, 2007). However, where climate scientists may have struggled to convey warnings, engineers, who have good experience at assessing unusual risks, have been reluctant to consider the potential worldwide impacts of their projects. This has resulted in industry being slow to change in regards to implementing low carbon solutions. Engineers have tended to concentrate on mitigation of dangers to the UK and its infrastructure, whilst the potential danger to life from carbon emissions released from construction projects has so far been given little attention as a construction risk, even though it is generally accepted that GHG are causing climate change (Thornley-Walker, 2010).

This thinking is supported by Nick Raynsford former MP who also stated that ‘ looking back a decade on; there is a general agreement that progress has been made but not going as far or as fast as many had hoped’ (Wolstenholme, 2009). Although it is recognised that there was a willingness to change (Wolstenholm, 2009, HM Government, 2013a, HM Government, 2017a), the level of change within the construction industry has not be at the level expected (Farmer, 2016). The construction sector has already fallen behind the UK Government goal (HM Government, 2013a) to halve carbon emissions from the built environment (Giesekam, 2015). The economic climate has played a significant part in the lack of progress, due to the lucrative nature of the industry and the lack of challenge and competition, to achieve the additional drivers. There is now another opportunity to benefit from the economic crisis and increasing social awareness to rejuvenate the enthusiasm and willingness within the construction industry to implement change (Egan, 1998, Wolstenholm, 2009, HM Government, 2013a, Farmer, 2016, HM Government, 2017a, HM Government 2019a).

Paul Morell noted that: *‘It is vital that industry plays its part in allowing the transformation to a low carbon future, developing new products and services, building skills and capacity, and making the transformation in its own structure and practice that will deliver a transition to a low carbon-built environment that is both affordable and assured. The ICE’s Infrastructure trajectory is a direct response to the challenge. It encapsulates what needs to change at all levels to ensure infrastructure is fit for purpose for a low carbon world…’* (ICE, 2011). However, in a move to change this stance a key organisation providing guidance to industry is the Strategic Forum for Construction which was re-launched in 2016 with the publication UK Government Construction Strategy 2016 – 2020 (HM Government, 2019c). The following extracts on taking a whole life and sustainable approach are particularly pertinent as is section 3 of the action plan:

> ‘45. As major construction clients, government departments must demonstrate clear leadership in areas of whole-life cost and whole-life carbon. The Construction 2025 industrial strategy targets a 50% reduction in greenhouse gas emissions in the built environment. The ICR has established how increased resource efficiency and a reduced carbon footprint can facilitate reduced cost, both upfront and during the whole life of the built asset;

47. Meeting sustainability objectives and driving down the uptake of innovative approaches to improving sustainability would be considered by the Strategic Delivery Group. This would be co-ordinated with the Green Construction Board on the ongoing outputs of the ICR. Government contracts will encourage innovative sustainability solutions on carbon reduction where value can be demonstrated'.

Table 2.1 Section 3 Action Plan Greening Government Strategy 2016 – 2020 (HM Government, 2019c)

Ref	Theme	Objective	Specific actions and timescales			Measures
			2015/16	2016/17	2017-20	
3	Data continued	3.6 Develop data requirements and benchmarks for measurement of whole-life cost and whole-life carbon (embodied and operational).	Establish what data is currently captured by departments and industry and what needs to be captured to support development of whole-life approach.	Agree KPIs to be collected in support of whole-life cost and whole-life carbon approach linked to GSL. Develop web based ability to collect whole-life cost.	Collect KPIs to measure whole-life cost and whole-life carbon. Draw early conclusions and form recommendations for future approach if possible.	Common standards established that can be used to assess whole-life cost and whole-life carbon

In support of a wider industry change Publicly Available Specification (PAS) 2080 (BSI, 2019) specification for carbon was launched at the second ICR event. The PAS 2080 (BSI, 2016) guidance states that: 'PAS 2080 provides a common process to encourage the right behaviours and approaches from clients, constructors, designers and product suppliers to deliver reduced carbon, reduced cost infrastructure'. It provides a common framework for all infrastructure sectors on how to manage whole life carbon management when delivering infrastructure. Reducing carbon footprint of infrastructure projects brings material, energy and labour efficiencies that reduce capital and operational costs, bringing savings from design to decommissioning (BSI, 2016). To conclude the requirement for industry to play its part has been clearly established.

Leading government organisations such as Environment Agency (EA) are adopting the recommended approach. The EA has aligned its FCRM sustainability strategy and delivery plan to the same themes of leadership, culture and communication, metrics and governance, commercial solutions and innovation and standards (EA, 2016c). This has been further updated in line with their e:Mission 2030 strategy which now also takes into consideration the following themes: lead the response to the climate emergency; deliver environmental net gain; create benefit for people and communities and reduce and optimise use of resources (EA, 2020f).

With UK commitment and an inconsistent response from the wider construction industry the opportunity for the public sector to tackle climate change, reducing their carbon emissions within their construction projects whilst reporting directly to government should be a key opportunity to drive industry change particularly within the water and FCRM industry. The EA (2009) stated 'Climate Change is a significant additional challenge; however, it may in fact facilitate the development and deployment of new infrastructure, technologies and management systems, which could contribute to the 2050 low-carbon target'.

2.5 Public sector and Flood and Coastal Risk Management (FCRM) construction

The low carbon infrastructure trajectory refers to flood risk and water management, stating that 'the UK's approach to flood risk management will need to continue to shift from a reliance on large capital carbon (CapCarb) intensive physical defences to a broader management of risk, combining defences and measures to alleviate the impact of floods. Sustainable urban drainage systems (SUDS), which in most cases use less concrete, are replacing some traditional drainage systems on new developments and envisage a retrofit of existing development and redevelopment with SUDS were feasible. Alternative concepts such as decentralised water and sewerage, green roofs and green walls, water neutrality and rainwater harvesting and greater peak flow attenuation could all have parts to play in a lower carbon flood risk management. Where traditional defences are deemed to be required, opportunities to use these structures for multiple purposes such as transport links or energy generation should be embraced' (ICE, 2011).

ICR (HM Treasury, 2013) and PAS 2080 (BSI, 2016) note that greatest carbon savings can be made at appraisal stage by selecting the best strategic options before detailed design and construction even begin. 'Greater engineering input will be needed in the appraisal phase leading up to decisions about asset investments to ensure decisions are made on a whole life basis with low carbon as one of the key drivers alongside capacity, reliability, system resilience and of course cost' (ICE, 2011). This view is supported by Henderson (2009) who states that 'planning can make a major contribution to tackling climate change'. There are two key avenues for this change to occur (Henderson, 2009):

a) Shaping decisions that reduce CO_2 emissions;

b) Positively building community resilience to problems such as extreme temperatures and flood risk.

The EA currently monitors the amount of carbon its produces in the course of its work. However, there is further work to be done on informing options regarding the carbon predicted in order for informed decisions to be made. It is this avenue of shaping decisions that can be improved upon in order to effectively challenge and visibly reduce CO_2 emissions.

As part of its FCRM responsibilities, public sector organisations have a statutory duty under the Environment Act 1995 (HM Government, 2019d) to protect, restore and enhance the environment when carrying out flood risk management activities and to comply with the requirements of European and National legislation. UK Government committed to providing £2.5 billion capital investment to reduce risk of flooding and coastal erosion between 2015 and 2020 to support this work (EA, 2013); with an update of £2.6 billion investment between 2015 and 2021 (HM Government, 2019e). The capital carbon impact of this construction programme feeds into the reported statement of UK emissions as required by the Climate Change Act 2008 and will have a significant impact on the UK's carbon targets.

For the EA in particular its carbon reduction targets for construction works have historically only been a reduction of 10% carbon from appraisal to end of construction. This target had not changed in 10 years, until in 2015 the EA launched its new 40% capital carbon reduction target as part of its sustainability strategy, e:Mission 2020 (EA, 2015b). The e:Mission target runs from 2015 to 2020 and at a project level this runs from options appraisal stage to end of construction (EA, 2015b). Organisations such as the EA have made public commitments to meeting iconic carbon reduction targets for capital (40%) (for each project/programme) and operational (45%) (compared to 2006/07) by 2020, supporting the Greening Industry Commitments (HM Government, 2018b) which are set out by the Green Construction Board sub group. In the latter stages of this research the organisation has progressed its future commitments through its e:Mission 2030 (EA, 2020f) sustainability strategy and the commitment to net zero by 2030 (HM Government, 2019i).

The UK Green Building Council (2017) has undertaken a recent review of carbon target setting. Its recommendation is the 'establishment of a whole life carbon target for the infrastructure industry based on climate science and from which organisations can derive commensurate targets'. Having such an industry wide target should establish a more streamlined approach to reducing carbon with all infrastructure parties working towards a common target. However, as the UK Green Building Council notes, the monitoring and reporting of carbon reductions against a common target is critical to its success. In public sector frameworks, the requirement to include sustainable and environmental requirements is often added as a 'soft' target rather than a 'hard' target that results in financial penalties. As an example, UK EA procurement methods require that sustainable outcomes are attained, in line with Greening Government Commitments and its environmental management system, accredited to ISO14001 and the EA Eco-management and audit scheme (HM Government, 2014b). These detail sustainability requirements that suppliers are required to adhered to, including the completion and provision of a carbon calculator for each project. It has been, unclear how non-compliance, with the completion of a carbon calculator to monitor carbon usage, transcends into financial incentives or penalties for suppliers (EA, 2013). Through the course of this research, this has progressed further with EA including programme level incentives and quality defect contractual conditions, within its next generation supplier framework arrangements, this is supported by a collaborative approach with supply chain partners to improve approach and project outcomes (EA, 2017b).

2.6 Organisational culture and leadership

UK Government is continually under pressure to demonstrate value for money with public spending. Irrespective of whether it is a public or private sector organisation, companies need to restrategise and reorganise their structures and processes in order to make change happen (Doppler, 2001). 'Enlightened thinking' is required to help with the cultural change away from organisations current practice to ensure that it can 'create an environment that incentivises innovation and speeds up the modernisation process' (Wolstenholm, 2009). In order to make these changes, a better understanding of organisational culture, including the ethics of an organisation along with the effect of leadership style is required.

2.6.1 Organisational culture

Organisational culture is defined as: goals and measures; customs and norms; training; ceremonies and events; management behaviours; rewards and recognition; communications; physical environment and organisational structure (Galpin, 1996). It is the 'shared assumptions, values, and beliefs, which determine how we behave' (Mayhew, 2016). Ralf

Mayhew (2016) also states that ‘Culture is all about relationships. As a leader you will only find effectiveness if you can relate to those you are leading and help move forward’. Culture is also viewed as the foundation that establishes the trust that impacts on the degree at which employees buy-in to change and highlights the commitment to drive and sustain change. In addition to this, it focuses on employee willingness to share information and collaborate, which ultimately determines organisation ability to survive disruptions, and its ability to advance (Alavi & Kayworth, 2005; Barney, 1986; Janz, 2003; Taylor, 2013). According to Gaplin (1996) there is no single component to describe organisational culture as each element is individual to the organisation and relies on how each element interacts on a day-to-day basis. Understanding and diagnosing organisational culture can assist in implementing the type of change needed and establishing organisational readiness for change (Burnes, 1996; Sundar, 2013).

What happens in organisations and reasons for this point to the ‘true culture’, the behaviour of employees may illustrate what the current culture is, and can change what an organisations’ culture can be; each individual in an organisation is part of a culture, and therefore can affect it. The repetitive nature is what makes ‘something cultural’, the only way to change this and manage change is to ‘create a different pattern which stands opposed to a culture’s rhythm’ (Mayhew, 2016). When viewing an organisation as a Complex Adaptive System (CAS), similarities and challenges can be observed, organisational culture is a ‘complex’ make up that cannot necessarily be defined or categorised. It is however through the behaviours and traditions a result of interactions and synergies between people, process and systems which cannot be fully predicted by studying the properties of individual components alone; or how a single change is to be successfully implemented or sustained. The culture of an organisation is about the ‘way things are done’ and likely to be dictated or driven by organisation structure or identity (McLennan, 2019). Breaking current practice requires creating different ways of working and ‘then exploiting the habit-trigger to direct attention in a new way’, by promoting different initiatives and rewarding those who adopt these initiatives (Mayhew, 2016). This view is also supported by Gaplin (1996) who states that ‘… the primary motive for managing culture during change is to implement and sustain those changes. Too often, executives and managers struggle when implementing changes because they don't understand how to make them important to employees …’. Bascal (2009) emphasises that the success of organisational change requires an understanding of how individuals change, associating this understanding with specific phases such as preparation, acceptance and commitment whereby individuals gain an understanding of the changes and therefore automatically have a positive acceptance. In contrast Kubler-Ross and Fisher (2009) focus on the psychological changes associated with an individual's positive and negative feelings and reactions. Their reactions are different, and this can lead to negative attitudes towards their work, and then in turn make them risk averse and afraid to innovate (Scott, 1989).

Brodnick and Krafft (1997), put forward a series of results from complexity theory, that are relevant to organisational environments such as: all organisations are potentially chaotic; are attracted to identifiable configurations; move among dynamic states through a process of division; functionally accurate forecasting is impossible on a broad scale and for the long term; cause and effect are not closely related in time and space; massive interventions may have insignificant results and small interventions may have massive results; and that similar actions taken by institutions will never lead to the same result (quoted in Phelps and Hase 2002).

Complexity theory notes the need to understand the interaction between the parts to be able to understand the whole, in order to understand an organisational culture and its ability to sustain a change, the interaction of individuals, their behaviours and reactions to a change in process or system, the operation and functionality of the system and process also need to be understood in order to understand the organisational culture change. The ability for individuals to cope with change varies, for some not enough pressure leads to boredom and low self-esteem. The correct amount of pressure can be a challenge improving performance and innovation, for others too much pressure can lead to feeling out of control and poor quality of work, resulting in stress and a loss of confidence in their ability (Willis, 2008). Kotter and Schlesinger's (2014) six change approach method for overcoming opposition are mirrored with Galpins' (1996) organisational culture components, which takes a step further into how methods for change can be sustained through knowledge management. Hogg, (1996) believes for a public body employee commitment is the way forward, utilising a marketing strategy of 'trust, empowerment and effective communication'. However, trust replies on having the confidence that people will do what they say they are going to do or are competent to do the things they say they are going to do (Mink, et al. 1993).

2.6.2 Ethics

The ethics of an organisation and its employees also need to be clarified. Frewings (2009) describes ethics as 'actions that exceed a legal compliance'. For many of today's public sector bodies striving to achieve high professional ethics and standards it is all part of their Corporate Vision for the future. In the case of the EA, Creating a better place, our ambition to 2020 sets out the vision, purpose, principles, culture and people. With the foreword from the Chief Exec stating *'how we do things in the Environment Agency is as important to me as what we do'* (DEFRA, 2018). This sets a plan by which the organisation can be measured both internally and externally, but strives to move the boundaries of modern-day business activities. This echo's the ethos of Frewings (2009) who states that the 'underlying approach is to define and apply ethics in the area between legal compliance and moral expectations'.

With the intention of fulfilling the moral ethics within its corporate strategy public sector organisations are reliant on their work force and that of its suppliers to achieve these goals through the fulfilment of their construction projects. The 'ethos (the values)' of an organisation is often driven by 'those in authority through governance processes and procedures' (McLennan, 2019). Ethics promoted by organisations are largely supported by their own workforce, who are highly motivated and passionate about the environment in which they live and work in, which in turn is part of wider organisational culture. Not only does this add another dimension to construction project teams, it also ensures that suppliers are openly challenged on their performance and commitment. Understanding what motivates individuals or organisations and the relationship between the two is essential to getting jobs done right. There are many theories on motivation ranging from the early ideas on work motivation: Scientific Management and the work done by F. W. Taylor (ASME, 2019), Hawthorne's experiments with the Human Relations approach, through to the development of the theories of the nature of work motivation (Harvard Business School, 2019). What motivates individuals is covered in Maslow's hierarchy of needs model (Maslow, 1943), Alderfer's (1972) modified Existence, Relatedness and Growth need hierarchy model and McClelland's achievement of motivation theory (Management Study, 2019). The combination of motivation and professional ethics can be defined in one word: 'Integrity'. For public sector organisations' motivation and integrity in its workforce and supply chain, are essential to ensuring high moral and professional ethics are met, not just on their own construction projects but also within the community around those projects.

2.6.3 Leadership styles

In order for any initiative to be a success, an organisation's workforce and leaders need to be bought into the change; public sector organisations frequently undergo changes, from organisational structure to systems and processes. Low carbon as an initiative requires further commitment as a change in the ethos and approach to everyday tasks and achievements, is required to truly achieve and embed a low carbon culture and approach. Within public sector this requires strong, focused and committed leaders. Who will inspire, motivate and succeed in embedding low carbon from a change initiative into the fabric of the way an organisation goes about and undertakes its everyday tasks.

Schein (1985), states that the function of organisational leadership is to establish, maintain and evolve an organisations' culture, in order to allow the organisation to perform efficiently. Mayfileds' (2013) 'Value Ladder' supports this thinking but looks in more detail at the leadership behaviours, stating that there are two vital leadership behaviours:

- 'A leaning to people, evidenced by the effort a leader makes in reaching out to stakeholders, as measured by the amount of their discretionary time spent in engaging people as opposed to task-orientated work;
- A leaning to action, where the change manager 'pokes the system' in a considered risk-taking manner, observes the response, and adapts'.

Both are required to ensure change is successful. In addition to this, leadership levers, what 'leaders do or say before, during or after a change', can influence the successful embedding of a change initiative. Individuals will look at the response a leader has to a particular event or situation and decide how they will respond dependant on their response (Smith, et al., 2014). An example of this is the EA Chairman Sir James Bevan, who in Febuary 2018, wrote a LinkedIn article referencing Druckers (Management Centre, 2019) 'Culture eats strategy for breakfast', and recognising that as a Chief Executive one of his most important things to do is to nurture a strong culture; that as a leader he talks about the EA Way: the culture of the organisation (Bevan, 2018). Another view is provided by McCalman and Potter who categorise contrasting leadership models, relative to cultural change work. The first is 'formal leadership', an individual who is an authority figure, who has staff reporting to them and is equipped to lead 'cultural reproduction'. The second is 'transformational leadership', an indivdual who has followers who of their own free will follow them, and is used for ‘advancing the need for and accomplishment of cultural transformation’. Both forms of leadership are required in order to lead cultural change (McCalman, 2019).

2.7 How cultural change can affect the success or failure of new initiatives

Change needs to come from both a company and individual level. A ‘cultural change’ needs to occur within an organisation when major change is implemented (Scott, et al., 1989) and in order for a major change to be successful, a sense of urgency needs to be established and a clear understanding of the internal and external drivers required (Kotter, 1979). Phelps and Hase (2002) state that: ‘From a complexity perspective development and change is viewed as a natural and evolutionary process which is neither imposed nor random (Doll, 1997). Rather, it is the interaction among component parts and the ways that the systems organise which promote change. Emergent structures are not outcomes in themselves but in turn influence future events, making possible the evolution of qualitatively different kinds of systems (Mihata, 1997). Complexity views change as adaptation stemming from the interaction, alignment and organisation of agents into higher levels of complexity (Lee, 1997)’.

As an example, the case of the leading government organisation EA and their supply chain, the sense of urgency comes from the need to save the environment alongside government drivers for low carbon construction, BIM and efficiency; these internal and external drivers have been relayed to supply chains via framework requirements. In principle the targets in which all of the organisations represented have agreed to, are set at client organisation level, framework level and contract level. However, the order in which these initiatives are prioritised above others, often comes down to individuals representing each project and their interpretation of the targets and their resistance to implementing changes required. Where as they should all be equally important, it is often the case that cost reduction and efficiency are prioritised higher than carbon as long as there is a reduction in the carbon recorded between appraisal, detailed design and construction phases there is less effort applied to strive for greater improvement (EA, 2018) .

Since cultural change has not occurred to its full potential in the last decade (Hall, 2010) how are we to ensure that the next decade is any different? According to Burners (1996) ‘managers need to have extensive and deep understanding of strategy, structure, systems, people, style and culture'. This view is supported by Kotter and Schlesinger (1979) who believe establishing a sense of urgency and understanding of the internal and external triggers for change, are imperative to the success of organisational change. When a major change occurs in organisations, what actually happens is 'corporate culture' changes (Scott, et al., 1989). Galpin (1996) states that 'effective implementation of organisational changes requires that changes in operations, systems, procedures and the like be clearly connected to an organisation's culture'. Making this connection embeds change in to the day-to-day life of organisations, sustaining desired effects (Wolstenholme, 2009, Farmer, 2016). Having a positive acceptance of a change is dependant on how individuals change and understand these needs (Bascal, 2009). This view is also supported by Scott, et al. (1989), who state that a lack of understanding and awareness of individual change may lead to a negative attitude towards their job, making individuals risk averse and afraid to innovate.

Motivating future generations through education and training; or engaging and incentivising employees, in order to deliver the changes required, supports the need to attract the right calibre of talent into the industry; this effectively utilises avenues currently available through professional bodies and learning institutions to promote a more 'holistic learning across disciplines' (Wolstenholme, 2009; Henderson, 2009; Hall, 2010). Learning however needs to incorporate both 'hard' and 'soft' skills. By definition, hard skills tend to be processes and systems, and soft skills more from the behavioural skills. In order for this to be achievable the education system needs to take into account the ability of individuals to engage collaborative supply chains in which they work, for example Project Managers need both the 'hard and soft skills' available to achieve the role they undertake. Winter (2003) highlights that the 'hard' system perspective has a clear objective or goal and a management process. The 'soft' system perspective is an ever changing flux of messy situations and the process of managing.

It is therefore on this basis that by promoting low carbon the greatest change can be achieved collectively across the construction industry (HM Treasury, 2013). Ainger (2012) emphasises the need for collaboration and improved knowledge sharing to rapidly drive forward the commercial applicability of innovative solutions within industry to the broad dissemination stage; and considers that this method allows diversity of approaches to challenges, allowing a number of different attempts to take solutions forward with a quicker route to adoption of solutions as standard across the industry (Ainger, 2012). This, Ainger contends, is required if the decarbonisation challenge is to be answered with any effectiveness and will need to be incentivised by DEFRA and OFWAT (Chisholm, 2013).

According to the ICE (2011), low carbon infrastructure is defined as a ‘similar level of service from existing networks but with greatly reduced carbon emissions over traditional approaches’. Waller (2013) states that ‘collaborative working relationships can increase efficiency with less defensive and more constructive mind-sets; meaning parties pool knowledge and effort and focus on successful outcomes for all participants. Anglian Water challenged its standard approach whereby ‘design engineers followed a four-stage process to reduce embodied carbon impacts: challenging the need to build any new structures, identifying which structures/assets could be reused, identifying alternative lower embodied carbon materials and finally using recycled material and reducing the quantity of raw materials’ (ICE, 2011).

Cole (2004) describes how early management theory can be divided into two main groups: (i) practising managers such as Taylor and Fayol, who base their perspective approaches on what managers should do to fulfill their leadership function and (ii) social scientists, such as Mayo and McGregor, who were academics, researching human behaviour in the workplace. These theories developed further with Maslow's hierarchy of physiological and psychological needs and other motivational theorists such as McGregor, Hertzberg and McClelland. With these theorists in mind building the right team and ensuring that the right people are doing the right job is all part of building a team and an organisational culture. *‘Participants should be selected on more traditional criteria such as capability, approach and systems and processes plus cultural criteria such as behaviours, commitment, alignment with the client team and potential for the combined team delivering outstanding results’* (Waller, 2013).

All supply chain partners from client, cost consultant, design consultant, site investigation contractor, main contractor and sub contractors, to end user all need to have a wide understanding of project objectives. ‘Project Management is being viewed as the 'new' form of general management which enables organisations to integrate, plan and control schedule-intensive and one-of-a-kind endeavours in order to improve overall organisational performance' (Pant, 2008). Whereas McCreery (2003), notes that the training and development of Project Managers is difficult due to the large knowledge base needed due to the fact that project management is both theory and practice based. Winter (2003) supports this view and states that, 'all practical action is theory laden, whereby theory leads to practice and practice generates theory, neither are prime as the process regenerates itself'. However, according to Carbone and Gholstone (2004, quoted in Pant, 2008). This view is supported by El-Saaba (2001, quoted in Pant, 2008) who adds that 'human skills of project managers have the greatest influence on project management practice and technical skills the least'. It is the human element that also has the greatest influence on organisational culture affecting the shape and succes of orga1nisations.

Whereas an organisations success and project level outcomes maybe achievable, the additional aims of low carbon and reduced cost has over the last decade been reliant on client lead approaches. This needs to change 'for the supply side to demonstrate how it can create additional economic, social and environmental value through innovation, collaboration and intergrated working' (Wolstenholme, 2009). McLennan (2019), states: 'relationships in business are important because they are the critical aspect of sustainable success and developing, performing and maintaining effective operations. This is equally true in both public and private sectors, but ultimately it is the interaction of relationships between organisations that creates the dynamic of a better business'. In order for this to be achieved both client and supply chain cultures and organisational set ups need to be adapted. One approach is to have 'minimum technical requirements and outcome specifications' on what is to be promoted (EA, 2013).

2.8 Publicly available carbon tools and standards

'Monitoring and reporting of carbon emissions is of great importance because it facilitates the understanding within companies of their emissions profiles and where the opportunities for reductions lie' (Chisholm, 2013). The main methods for measuring embodied carbon is either by an : input output method, which utilised macro-economic analysis and process – base method that utilises information from life cycle assessments (Kennelly, 2019). There are several carbon calcultors available to the public and construction industry free of charge. The analysis of materials, resources and methodologies can be assessed using online tools. However, not all carbon calculators are suitable or appropriate for construction especially within FCRM construction. This is due to the content not covering all aspects of FCRM works or due to aspects highlighted by McKinskey (2018) who state that social tools play a critical role in how technology overall can encourage organisational change; his survey, focused on three key areas were participants had a role in adoption of tools within their organisations work, these were:

- Real-time interactions;
- Ability to collaborate with specific groups of individuals;
- Accessibility across multiple organisations.

The following calculators are available for use by the infrastructure industry (Circular Ecology, 2017):

- AggRegain Carbon Dioxide (CO_2) Emissions Estimator Tool – For Aggregates (Agg-net, 2019);
- Asphalt Pavement Embodied Carbon Tool (TRL Ltd, 2018);
- Carbon Build Neutral (Build Carbon Neutral, 2019);
- PAS 2050 Carbon Calculator for Stoneworks (GHG Protocol , 2019);
- The Highways Agency Carbon Calculator for Construction (HM Government, 2019f);
- Transport Scotland Carbon Management Scheme – Carbon Calculator for Road and Rail Schemes (Traffic Scotland, 2019);
- Environment Agency Carbon tool (EA, 2016b).

Carbon reporting within UK public sector FCRM has been in place since 2005, and carbon monitoring within the wider water industry has been in place since the 1990s. The commonly used Carbon Accounting Workbook (CAW) (UKWIR, 2009) used across the industry assists with carbon reporting to OFWAT; University of Bath carbon data is still used. However, it is essential that monitoring and reporting of carbon is standard across the industry. 'Monitoring and reporting of carbon emissions is of great importance because it facilitates understanding within companies of their emission profiles and where the opportunities for reductions lie.' (Chisholm, 2013).

The collation of carbon data at a project level comprises complex communication processes between numerous project participants involving large amounts of information that often causes errors and omissions during design and construction (Eastman et al., 2008; Sebastian, 2010). This calls into question the reliability of data and the consistency in which data is gathered and reported. Each of the publicly available carbon tools are stand-alone and are specific for their choosen audience, available through online or Excel based systems. A clear step forward is required for the next generation of carbon tools which is to use the carbon data at source and BIM as the basis of an integrated system approach. According to Sebastian (2010) 'BIM comprises collaboration frameworks and technologies for integrating process and object-orientated information throughout the life cycle of buildings in a multi-dimensional model. BIM information sharing among project participants from different disciplines can be centralized and coordinated effectively'. It is expected that this could improve the quality of carbon data and ensure that carbon reporting is more consistent across the infrastructure industry. In order to achieve greater leadership in promoting and prioritising carbon reduction, solutions are required along with a fundamental cultural change and investment focus within the infrastructure industry to ensure that carbon calculation is undertaken utilising the same quantification process, with carbon data being provided at source.

Succar (2010, cited in Sebastian, 2010) sets out a set of guiding principles purposely developed to measure the specifics of BIM performance in conjunction with the BIM Quick Scan tool. The tool is intended to be used to scan an organisation over four main chapters that represent both 'hard' and 'soft' aspects of BIM namely: organisational management; mentality and culture; information structure and information flow and tools and applications. The guiding principles are as follows:

- Accurate: clear, non-falsifiable and allow accurate, repeatable assessment;
- Applicable: can be utilized by all stakeholders across project life-cycle phases;
- Attainable: benchmarks can be achieved through progressive accumulation of defined actions;
- Consistent: when conducted by different assessors, measurement yield the same results;
- Cumulative: benchmarks are set as logical progressions; deliverables from one benchmark act as pre-requisites for another;
- Flexible: assessments can be performed across markets, organization scales and their sub divisions;
- Informative: measurement provide 'feedback for improvement' and 'guidance for next steps';
- Neutral: measurements do not prejudice proprietary, non-proprietary, closed, open, free or commercial solutions or schemata;

- Specific: metrics are well defined and serve industry-specific assessment purposes;
- Usable: metrics are intuitive and can be easily employed to assess BIM performance.

These principles have similarities to PAS 2080 (BSI, 2016).

2.9 Low carbon solutions

The clear message already provided by water industry is that carbon abatement is now not too high a price to pay and the general principle is that a solution which uses fewer natural resources is likely to involve less embodied emission there is less experience within the industry of accurately accounting for embodied emissions, although the accuracy is improving. As with operational carbon, there are tools for doing so, within the suite offered by UKWIR (2012, cited in Chisholm, 2013). In the case of Anglian Water, these savings have been identified through more detailed consideration and prioritisation of embodied carbon reduction within the design stage of new schemes, combined with active engagement of supply chains to in turn reduce its '10% by 2015' against a 2010 baseline. The target set for embodied carbon emissions, was 50% by 2015. It has been found that the capital expenditure (CapEx) schemes with low embodied emissions are commonly cheaper that more traditional solutions. This runs counter to the conventional wisdom expressed by water companies during PR09 (Price Review 2009). However, there is growing evidence that companies can both reduce their embodied carbon whilst at the same time also reduce their cost, though this requires a concerted and innovative effort (Chisholm, 2013). The ICR (HM Treasury, 2013) clearly states that low carbon solutions result in reduced cost and improved efficiency; this view is supported by Chisholm (2013) who states that 'there will be a point at which the price of energy and carbon will shift the balance of whole life cost assessment to operational expenditure driven rather than capital expenditure driven decisions and this is likely to underpin a carbon reduction initiative'.

Historically, schemes which sought to minimise carbon emissions were considered prohibitively expensive; however, given the strong link between energy consumption and carbon emissions and significant increases in energy prices over recent years, more energy efficient schemes, as well as those with lower embodied carbon, are increasingly seen to be considerably cheaper than more conventional options. Anglian Water, for example, have achieved considerable cost savings through placing an overt emphasis on carbon reduction from early design stages (Chisholm, 2013). National Grid (2019) case study on cutting carbon and cost, through the implementation of a 5% weighting on construction projects, shows how a new electricity substation at Wimbledon was built with a 20% reduction in carbon across the asset's life whilst saving £3 million in costs. Volvo (2019) through an electric site research project provides a case study of the world's first 'emission free' quarry. This involves the replacement of diesel vehicles with electric, resulting in a 98% reduction in carbon emissions, 70% reduction in energy cost and 40% reduction in operator costs. Croner-i (2017), details that targets, legislation and motivations for carbon reduction from building and construction projects can be achieved, with examples of energy-efficient buildings and annual energy cost savings achieved. New Civil Engineer (2018), provides an outline progress review of the infrastructure sector five years after the publication of the ICR (HM Treasury, 2013) it highlights that National Grid and Anglian Water are leaders in the field, but the majority of other companies are yet to fully implement measures to reduce carbon and cost across their businesses. Through interviews with clients and contractors, one of the key issues for this is a focus on other issues such as margins and skills with climate change seen as a future problem.

ICE Infrastructure Trajectory proposes as its 5th priority, for 'low carbon investment, the hierarchy requires that importance be given to better use of existing assets and ensuring that any new assets are made to deliver ever greater value' (ICE, 2011). Leading government agencies such as the EA are taking this ethos forward and ensuring that they operate as an asset management organisation in line with ISO55001. However, at a project level, focusing on specific carbon reduction areas such as materials, site establishment, transport, fuel consumption, future energy use and maintenance requirements, can lead to carbon and cost reductions, without extreme change of solution. 'The 80-20 rule, also known as the Pareto Principle, is an aphorism which asserts that 80% of outcomes (or outputs) result from 20% of all causes (or inputs) for any given event' (Tardi, 2020). This is further supported by Victoria and Perera, (2018) who applied Pareto's Principle to the identification of carbon and cost hotspots within a building, reporting that the identified carbon hotspots contributed to 72% of the capital cost and the identified cost hotspots contributed to 81% of the embodied carbon. According to Sathre and Gustavasson, (2007) research on construction material has shown that substituting wood material in place of other construction materials such as concrete and steel, can be an effective technique to reduce net GHG; generally lowers net carbon dioxide emission for three reasons: (i) manufacture of most wood products uses less fossil energy than manufacturing other materials; (ii) by-products of wood processing can be used as biofuel to replace fossil fuel; (iii) carbon is stored in wooden materials, leading to reduced waste as part of the overall solution. This is just one material, and there are other solutions such as alternative concrete mixes which can have significant carbon reduction outputs. However, these innovative solutions appear to be hampered by the need for certification and standards and the recognition that availability of timber is not finite. An example of this is the CE (European Conformity) marking; a Cemfree activator does not have a CE mark because there is no CE accreditation for this type of product. Cemfree contains no ordinary Portland cement (OPC) and therefore falls outside the remit of BS8500, and it also falls outside the remit of CE accreditation process. It therefore relies on client organisations themselves to be more innovative in approaches to alternative solutions and products in order to challenge traditional practices and use of alternative materials and solutions.

According to the Construction Leadership Council (2019) in order to achieve a net zero reduction by 2050 carbon emissions from the built environment industry needs to 'Act on Carbon: by setting carbon targets to design for low carbon, and to cut carbon everywhere for planned longevity'. The EA (2009) stated 'Climate Change is a significant additional challenge; however, it may in fact facilitate the development and deployment of new infrastructure, technologies and management systems, which could contribute to the 2050 low-carbon target'. ICR (HM Treasury, 2013) and PAS 2080 (BSI, 2016) note that the greatest carbon savings can be made at appraisal stage by selecting the best strategic option before detailed design and construction even begin. 'Greater engineering input will be needed in the appraisal phase leading up to decisions about asset investments to ensure decisions are made on a whole life basis with low carbon as one of the key drivers alongside capacity, reliability, system resilience and of course cost' (ICE, 2011).

2.10 Summary and link

This chapter outlines a review of current literature. Focusing on, international agreements and the effects of a changing weather patterns and more extreme climate events and how these are conditions are exacerbated by human expansion and the 'GHG effect', with CO_2 being a measurable factor that can be positively or negatively impacted by human influence. The UK Governments' commitment to climate change is evidenced through the Climate Change Act (2008), with ongoing prioritisation evidenced through carbon plans, greening commitments and route maps (HM Government, 2009, 2010, 2011a, 2011c, 2013b, 2014b, 2017b, 2019c). However, such commitment is not yet fully evidenced in its implementation with challenge across industry of its lack of priority and progress (Wolstenholme 2009, Farmer 2016, HM Government 2013a, 2017a, 2018a, 2018b, 2019a, ICE, 2009, 2011, 2020a, 2020b, 2020c). The role of leadership alongside a cultural change is promoted as essential to success in ensuring a sustainable and consistent change in organisational and industry culture. However, the need for more transparent and holistic learning, with practice and theory intertwined is necessary to ensure the UK construction industry and FCRM specifically are pushed and pulled into a new way of working.

The ingrained practices with UK construction and FCRM need to be in-line with government and organisational priorities, with a focus on building evidence for knowledge sharing and capability building. The utilisation of collaborative working and relationship building to align carbon and cost and to ensure that climate change is viewed with the necessary sense of urgency to make it real rather than a future problem to be dealt with by others. Existing and future tools and standards need to address future and emerging needs with real time interdependencies, collaboration and accessibility as a core requirement. Enabling and influencing future system changes that can empower rather than restrain teams.

Chapter 3 presents the research method in order to measure the variables (VAR) answer the research questions (RQs), complete the objectives (OB) and test the hypothesis (H).

CHAPTER 3: INITIAL CONCEPTUAL FRAMEWORK

3.1 Introduction

Chapter 2 presented a review of the literature relevant to the area of research, this chapter covers the initial process adopted along with the details of the conceptual framework for the study and covers the following areas:

- the importance and relevance of a conceptual framework in the context of action research is explained;
- the key issues identified via the literature review are discussed;
- the process for developing an initial conceptual framework for this study is discussed;
- the initial conceptual framework for this study is presented;
- the chapter is summarised.

3.2 Importance and relevance of a conceptual framework in action research

Action research is the process that moves from a clear objective to diagnosis of the problem and generation of a list of actions to solve the problem. It requires collaboration between the researcher and the organisation in order to solve organisational problems. The purpose of undertaking action research is to bring about change in specific contexts (Koshy, 2010); this view is supported by Meyer (2000) who maintains that action research's strength lies in its focus on generating solutions to practical problems and its ability to empower practitioners.

According to Coghlan (2014), whilst undertaking action research within the authors' organisation it is important to make sense of the organisational dynamics; this can be done through the use of a framework. In every field and subject area there are frameworks that can be used to make sense of situations and help predict outcomes. However, the whole holistic system needs to first be considered before a specific part can be focused on, this supports complexity theory, whereby within 'complex systems: emergent properties at any level must be consistent with interactions at lower level(s)' understanding the line of sight and the interactions across the organisation allow for 'recurring patterns' to be identified (Holland, 2014). In considering action research certain factors need to be considered before it is deemed suitable for any study (Research Methodology, 2018). The action research process works through three phases: Look, at the big picture and gather information; Think, interpret and explain the situation, its successes and deficiencies; Act, resolve issues and problems, formulating solutions to any problems (Stringer, 2007). The Action Research Spiral is a participatory study that consists of a sequence of self-reflective cycles. As within CAS, loops offer control for positive and negative feedback, making it possible for 'sub-routines' or supporting activities to be undertaken that are modified by surrounding activity rather than controlled by it, in this sense the activities undertaken as part of the implementation of WLCPT could be determined as 'sub routines' (Holland, 2014). The spiral is provided in Figure 3.1.

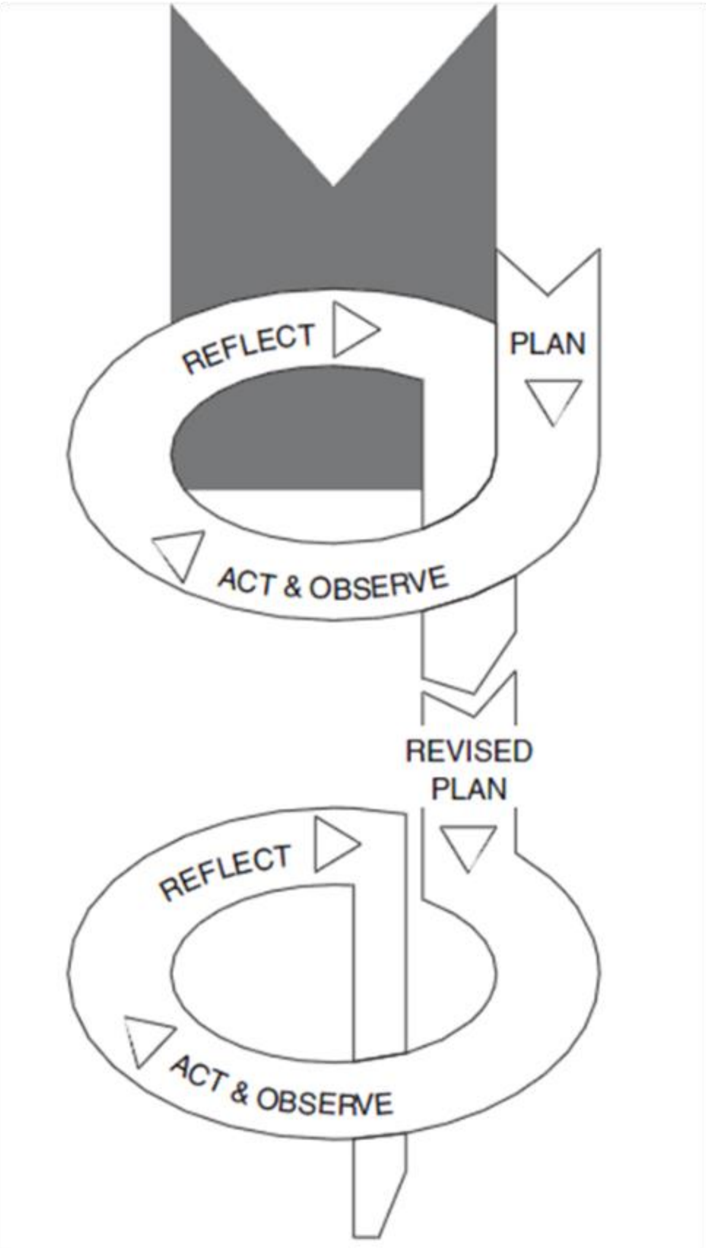


Figure 3.1 Action Research Spiral (Research Methodology, 2018)

The five sequences of the spiral are as follows:

- planning in order to initiate change;
- implementing the change (acting) and observing the process of implementation and consequences;
- reflecting on processes of change and re-planning;
- acting and observing;
- reflecting.

In order to ensure the prioritisation, the author is promoting, is central to this approach the organisational learning needs to be both understood and integral to the review process. This study has developed an initial conceptual framework, this has been based on a literature review and a review of the author's complex organisations' approach to capital carbon data collection and decision-making processes.

3.3 Key issues raised from the literature review

A literature review was undertaken and presented in Chapter 2 and a conceptual framework developed based on these initial findings. Key issues identified are as follows: increased climate change challenges (sections 2.1 and 2.2); need for greater action to reduce carbon across the wider construction industry (sections 2.3.1 and 2.4); role of UK public sector FCRM clients in success of reducing carbon within construction (sections 2.5 to 2.7); and need for empowering project teams within FCRM construction to reduce carbon (sections 2.8 and 2.9).

3.4 From the authors' organisational observation and personal motivations.

According to McNiff et al. (2011) action research is a generative transformational process, where claims to improved learning and practice generates further learning to improve practice; it is not a notion of working to a perfect end state. The author evaluates their own work, being an agent with 'the capacity for influencing their own and other's practices, with the potential to influence wider social change', and complete their research objectives.

Greater action to mitigate climate change can be undertaken in a more manageable and visual arena to help reduce carbon across the wider construction industry; ensuring that organisations take a leading role such as a UK public sector FCRM client. In order to successfully reduce carbon within UK public sector FCRM construction and to empower project teams to make the right choice; the sense of urgency and wider climate change challenges, need to be recognised. As more extreme weather events and natural disasters are becoming the norm rather than the extreme. Working within an organisation that focused on FCRM works to mitigate the effects of climate change, the author has undertaken a variety of roles from the project management of construction schemes, programme management, along with framework and contract management accountabilities, recognising from personal experience the need for empowering teams to make the right carbon reduction decisions.

3.5 Key concepts

As covered in section 3.3 the key issues raised have been explored further and reviewed as part of authors' own observations and motivations. These have been compiled into three key concepts for this study and can be found in Appendix A. The literature review and author s view, both confirm that a changing climate is increasing the effects of more extreme weather events of which flooding is a significant consequence and as such additional more robust FCRM schemes are required to reduce the risk and to protect people and property. This resultant need for flood risk reduction, in-turn contributes to climate change through the implementation and construction methods within UK public sector FCRM projects. This need is unlikely to diminish as the effects of climate change increase and become more extreme. Therefore, one approach is to mitigate and to reduce the carbon contribution, from the implementation of FCRM construction projects. This by no means will resolve the wider problem of climate change but does provide a tangible insight and awareness rising opportunity to the wider issue of construction carbon and how things can be done better and more sustainably.

3.5 Initial conceptual framework

The conceptual framework of the study is presented in Figure 3.2 and outlines how the WLCPT aligns to the complex system of the organisation. The key literature findings have been overlaid on this framework along with the areas of concern to be addressed.

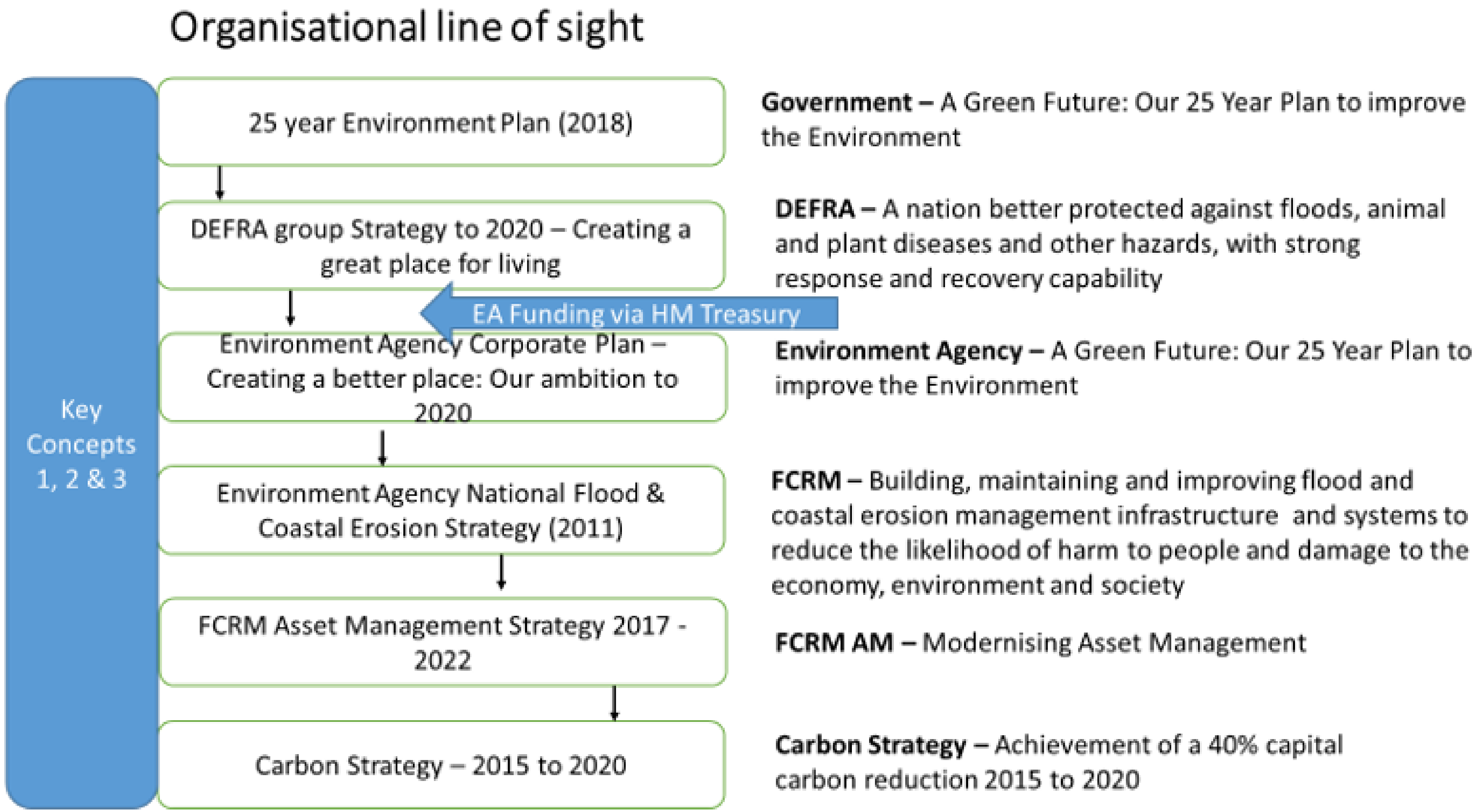


Figure 3.2 Key concepts and organisational line of sight

3.6 Summary and link

This chapter has elaborated on the process for a conceptual framework and illustrates how this can support an action research approach. It is developed based on literature and the author's own observations and illustrates the process for achieving the research objectives, thus:

- OB1: to investigate whether demography of professionals influences low carbon prioritisation
- OB2: to investigate whether organisational change influences low carbon prioritisation
- OB3: to investigate whether organisational carbon leadership influences low carbon prioritisation
- OB4: to investigate whether quality of training influences low carbon prioritisation
- OB5: to investigate whether organisational culture influences low carbon prioritisation
- OB6: to investigate whether tonne of carbon influences cost
- OB7: to investigate whether the quality of implementation of a whole life carbon planning tool influences cost
- OB8: to investigate whether type of training influences tonne of carbon
- OB9: to investigate whether low carbon promotion influences organisational culture.

Chapter 4 will provide the research methodology to support the initial conceptual framework.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

Chapter 3 presented the establishment of an initial conceptual framework based upon the literature review undertaken. Chapter 4 covers the research methodology, the design for the research method from inception to thesis write up and the journey this study has taken in its development and the right research direction. 'The methodology varies according to the research problems investigated, and therefore, identification of the most appropriate research methodology is essential to achieve the aims and objectives of the research and to ascertain the credibility of the research findings. Therefore, the selection of an appropriate research methodology is one of the fundamental aspects of any doctoral research in order to ensure the reliability of the research findings' (Malalgoda, 2014).

This chapter is structured as follows:

- the process adopted to establish the research problem and the aim and objectives of the study are detailed;
- the development process involving the selection of the:
    - research philosophy;
    - research approaches;
    - research strategies;
    - choices of methods;
    - time horizons, techniques and procedures.
- the validity and reliability of the research design;
- the research method summary.

4.2 Establishment of the research problem

The research focus has been defined based on the author's profession and area of interest. Utilising the author's profession has required from the outset an acceptable focus for the study which continuously requires focussing and re-focussing (Easterby-Smith, 2008). Collis and Hussey (2009) define research as a systematic and methodical process of enquiry and investigation with a view to increasing the knowledge domain. The research problem has been established based on the observations of the researcher, a review of relevant literature and expert opinion. The account that the researcher produces contains the description of the research (what was done) and explanations (why it was done and what was aimed for) (McNiff, 2011). A mixed method approach in the form of a survey and an action research is being used to evaluate whether the activities implemented and undertaken by the author is influencing other people's learning. To help the organisation and project management teams develop a better understanding of low carbon and the wider benefits it brings in regards to reduced cost; to encourage organisation leaders to better prioritise low carbon and to influence an organisational change. The activities undertaken are non-linear. This non-linearity, yields levels of organisation and hierarchies of which each level of hierarchy is governed by its own set of rules or laws; emergent properties at any level must be consistent with interactions specified at lower levels (Holland, 2014). A combination of top down organisation and industry influence and bottom up practical steps; the WLCPT development, training and guidance is a feature of a complex system, where the whole area of influence 'carbon reduction' and the activities undertaken through 'prioritisation' offer a key to new kinds of understanding (Holland, 2014). These steps are explained in the sections below. Figure 4.1 provides a flow chart of the research process. The iterative nature of the action research approach, is overlaid with Saunders et al. Research 'Onion' stages (2007).

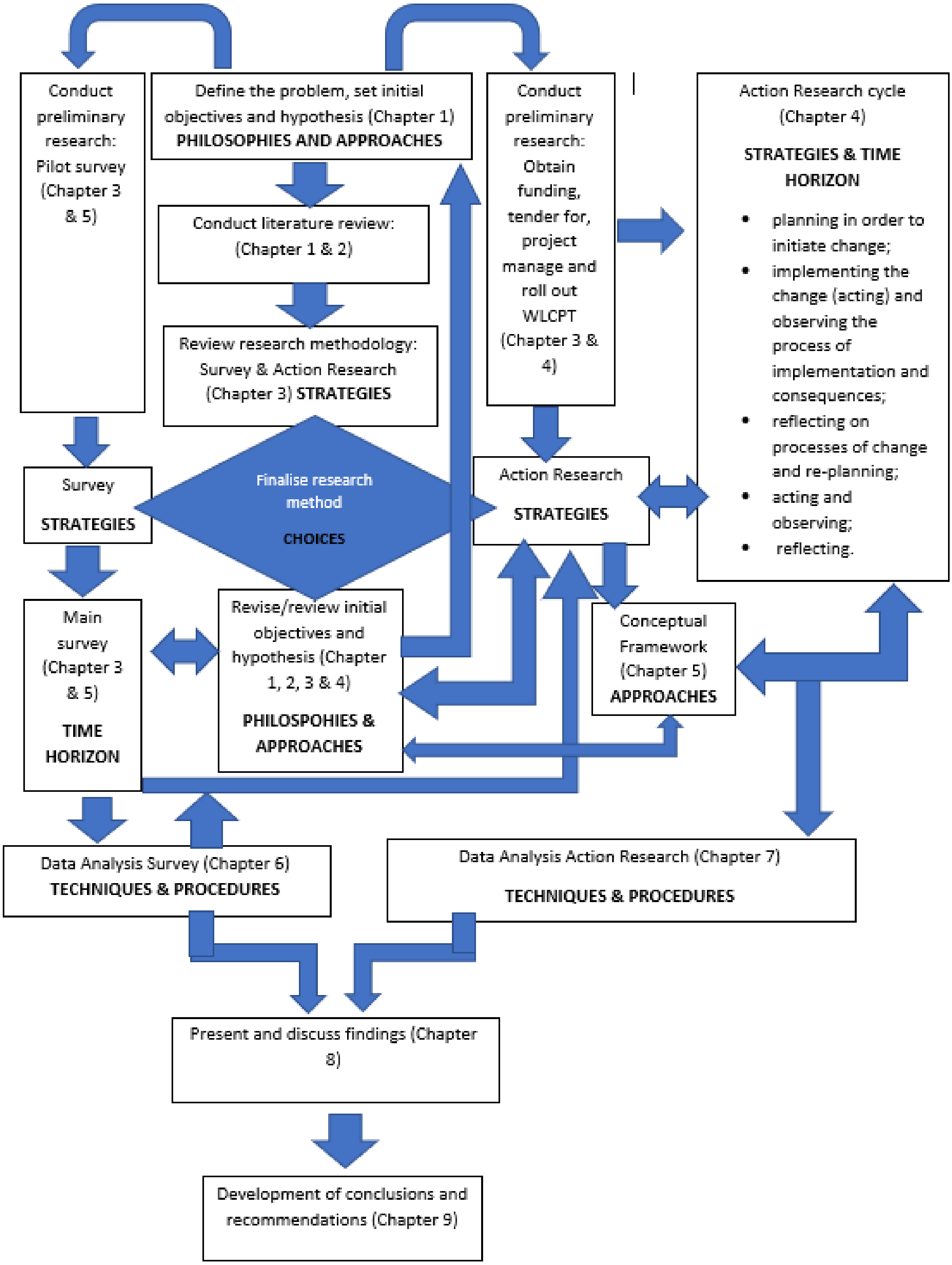


Figure 4.1 Research process

4.2.1 Researcher's area of interest

The author has utilised her work profession as a subject area that both holds a particular interest and that the author is capable of investigating. This is important when selecting a research area (Saunders, 2007; Remenyi et al. 1998). Therefore, the subject area has been defined as 'prioritising carbon reduction in UK public sector Flood and Coastal Risk Management (FCRM) construction'. This research will involve explaining what inspires the author to do the things she does, and what she hopes to achieve (McNiff, 2011). The consideration of a current topic of interest and practice, in addition to access to data sources and research limitations, such as resource constraints, time and the resources available to conduct the research and data availability (Fellows and Liu, 2003) has been factored into the initial interest.

With increased frequency in extreme flood events and the need to mitigate the effects of climate change within FCRM construction, the subject area selected for study is extremely relevant at the time of doing the research. A thorough literature review has been undertaken to establish the research problem. In a social context this research is undertaken with others, the ideas expressed began as other people's ideas, the author has made the ideas and processes her own in applying these in the context of UK public sector FCRM construction, therefore transforming these ideas into new opportunities and practices (McNiff, 2011).

4.2.2 Review of relevant literature

A critical review of the literature has been undertaken to narrow and focus the research problem. This systematic process of identifying the existing body of knowledge in a particular area of study (Collis and Hussey, 2009), has resulted in the development of a good understanding and insight into relevant, previous and current research in the field of study (Saunders, 2007). More importantly, the literature review process has identified gaps in the existing research and suggested research questions that address the gap (Eisenhardt and Graebner, 2007).

Based on initial assumptions in the subject area defined as 'prioritising carbon reduction in UK public sector FCRM construction', a literature review has been undertaken by referring to books, journal articles, conference proceedings, reports and websites. This has helped the researcher to gain an in-depth knowledge about the broader area of 'prioritising carbon reduction in UK public sector FCRM construction', organisational culture and cultural change.

The initial review of literature helped the author to narrow down the study area initially from UK construction to a more specific field of construction. UK public sector FCRM construction has a direct link to the author's strengths, interests and profession. Through the initial review of literature, it was recognised that public sector organisations have a key part to play in carbon reduction, narrowing this field of construction further and considering the author's occupation, offered a unique opportunity to distinctively define the area of research.

Although UK public sector FCRM have been identified as key research area in low carbon construction, the critical review of literature has assisted in refining initial research ideas. The review remains as an on-going process which requires refinement and modification as the study progresses, as new findings emerge all the time and it is important to reflect these (Easterby-Smith, 2008).

A more thorough review was undertaken on the following concepts:

- climate change and its effects;
- UK Government and its commitment to carbon reduction and its implications;
- UK construction and its commitment to carbon reduction and its implication;
- low carbon in UK public sector FCRM;
- organisational culture and leadership;
- publicly available carbon tools and standards;
- low carbon and reduced cost.

Following a critical review of literature, the researcher was able to establish:

- the research problem;
- the aim of the study;
- the objectives of the study;
- to develop the initial conceptual framework.

These stages were further refined based on a survey carried out of practicing UK public sector FCRM construction professionals

4.2.3 Research: aim, questions; objectives; hypothesis and variables

As detailed in Chapter 1, the research aim is to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). In order to achieve the aim: research questions; objectives; hypotheses and variables, have been established; details can be found in Table 1.1.

In adopting a research approach, the research questions are the key issues that form the basis of the author's approach, based upon the values and 'concerns' that the researcher feels are important and need to be addressed. The process of establishing the research problem, aim and objectives has been identified; the next section covers how the research method was designed to achieve the identified aim and objectives.

4.3 Research development process

The design method for this research has been based on Saunders' et al. (2007) research 'onion' as illustrated in Figure 3.1 and Figure 3.2. Rowley (2002) states that 'the logic that links the data to be collected and the conclusions to be drawn to the initial questions of a study'. This supports Saunders' et al. (2007) method design which provides guidance on how to select the most appropriate research method. The research 'onion' diagram has six layers, each indicating an important aspect which ought to be considered when deciding on the appropriate method, needing to be peeled away before reaching the data collection and data analysis stage. They include:

- philosophical stances;
- approaches;
- strategies;
- choices;
- time horizons;
- techniques and procedures.

It is argued by some researchers, like Keraminyage (2009), that not all of the layers are in the logical order as depicted in the 'onion', but all of the layers are important when selecting the research method.

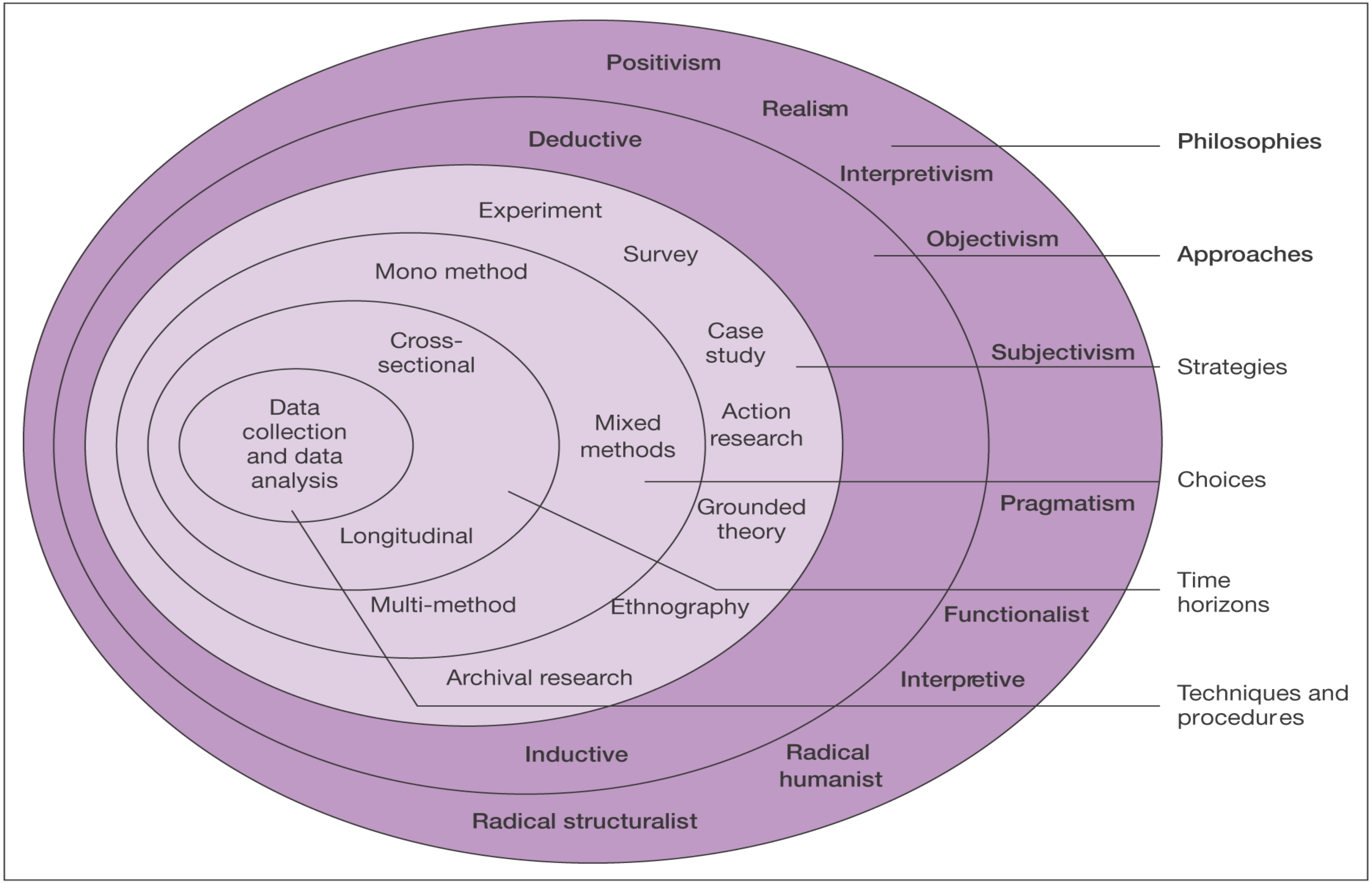


Figure 4.2 The Research ‘Onion’ (Saunders et al. 2007)

4.4 Research philosophy

The knowledge and understanding of 'research paradigms' relate to the philosophy around what (Epistemology), how (Ontology) and the role the researcher plays (Axiology) (Farrell et al., 2017). The research philosophy contains important assumptions; these are based on the way in which the authors views the world, and this underpins the research strategy and influences methods chosen as part of that strategy (Saunders, et al., 2017). Failure to think through philosophical aspects of research can affect the quality of research (Easterby-Smith, 2008). The next section explains the three major ways of thinking about the research philosophy: epistemology, ontology and axiology.

4.4.1 Epistemology

Epistemology is about addressing facts, i.e. what constitutes acceptable knowledge (Saunders' et al., 2017; Collis and Hussey, 2009). According to Collis and Hussey (2009), it is concerned with what is accepted as valid knowledge. In defining what acceptable knowledge is about this field of research, most climate scientists agree the main cause of the current global warming trend is human expansion of the 'greenhouse effect' (NASA, 2017); with the international Paris Agreement of November 2016 focused on limiting temperature increases through the reduction of carbon (UNFCC, 2017). The progress on reducing carbon within the infrastructure sector, has been limited with little progress made (Wolstenholme, 2009, Farmer, 2016, HM Government 2017a, ICE, 2020). Organisational theorists such as Schein (1992) have established that employee behaviours reflect organisational culture; there are many works on this subject area that focus on how organisational culture brings together its collective values (Needle, 2004; Mayhew, 2016, Coyle, 2018). The use of carbon calculators is an established method for measuring the carbon output or usage within construction, with many being in existence and publicly available (Circular Ecology, 2018). The utilisation of construction carbon calculators alongside climate change and its causes and organisational culture are acceptable knowledge areas.

The research aim is to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). The information incorporated into this research study is known to be true; due to rigorous testing and treated as fact. Therefore, the research will be viewed from an interpretivism perspective which argues that the author plays a role in making sense of and interpreting the data; emphasizing the meaningful nature of people's participation in social and cultural life, and whereby cultural existence and change can be understood by studying what people think about their ideas and meanings that are important (Saunders, et al. 2007).

Therefore, different people within construction roles and organisations may construct meanings in different ways even in relation to the same low carbon requirement. In terms of UK public sector FCRM construction, the researcher (author) is deemed to be part of the research and the reality is determined by people rather than by objectives and external factors (Easterby-Smith, 2008). As with self-study research, the focus of the research is the researcher, the kind of questions asked such as 'What am I doing? How do I improve it?' the researcher aims to show how they are accountable for what they do (McNiff, 2011). Therefore, interpretivism can be identified as the best way of enquiring into the research question.

4.4.2 Ontology

Ontology is the study of the nature of reality (Saunders, 2007), the study of being (Crotty, 1998), which raises the question as to what assumptions people would have to make about the way in which the world works. In other words, it is the philosophical assumption about the nature of reality (Easterby-Smith, 2008). It is the difference between reality and our perception of reality and how this influences people's behaviours. Objectivism, pragmatism and constructivism are three assumptions of ontology. Objectivism is whereby social phenomena and meanings exist separate to social actors. As an example, climate change the social phenomena impacts on the world's population, but whereby human knowledge is created by the nature of reality and not by people's thoughts (University of Derby, 2018).

Pragmatism takes the view point of social phenomena and social actors and deems that both approaches are valid and can see the topic from either side. Constructivism is the opposite of objectivism whereby the social phenomena is constructed by the social actors and ideas are constructed by human interaction and decisions. Constructivism and action research are highlighted by Carr and Kemmis (1986) who state that: 'action researchers accept that transformations to social reality cannot be achieved without engaging the understandings of the social actors involved. They accept that understanding the way people construe their practices and their situations is a crucial element in transforming education, but not that this understanding provides sufficient basis for achieving such transformations'. Connections between constructivism and complexity theory have also been highlighted by both Sumara and Davis (1997) and Doolittle (2000) (quoted in Phelps and Hase, 2002).

This research has aimed to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). A questionnaire and action research activities will look to enable completion of the following objectives:

- OB1: To investigate whether demography of professionals influences low carbon prioritisation;
- OB2: To investigate whether organisational change influences low carbon prioritisation;
- OB3: To investigate whether organisational carbon leadership influences low carbon prioritisation;
- OB4: To investigate whether quality of training influences low carbon prioritisation;
- OB5: To investigate whether organisational culture influences low carbon prioritisation;
- OB6: To investigate whether tonne of carbon influences cost;
- OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influence tonne of carbon;
- OB8: To investigate whether type of training influences tonne of carbon;
- OB9: To investigate whether low carbon promotion influences organisational culture.

In addressing these objectives, the influence of an action research WLCPT and the ways of influencing an organisational change does not have to be pre-described and structured, the outcome could vary depending on the organisation, environment (i.e. project), stage of a project lifecycle and the behaviour and viewpoint of individuals. The intended study could be positioned more towards the subjective stance. With innovative practices where the research is to improve the whole organisation, the viewpoint of individual changes to the collective, whereby the understanding groups share certain collective values that they wish to realise (McNiff, 2011; Marshal, 1999; Marshal, 2004). According to Farrell et al. (2017) research involving people is more complicated – it can be less objective and more subjective.

4.4.3 Axiology

It is the author's responsibility to understand and recognise how their role, values and opinions play a part in the collection and analysis of the research; this is opposed to trying to eliminate or balance the influence of it. Axiology can be classified into two opposing views, i.e. whether the reality is value free or value laden. This research is value-laden; whereby the choice of research area, research questions, methods, research design and data collection techniques and implementation, analysis of data, interpretation of data and conclusions would be a product of the values held by the researcher (Bryman and Bell, 2003).

In identifying the assumptions for the research, which is socially constructed and value laden, the next step is to explore the theoretical perspectives which govern the research philosophy. The study will investigate whether the prioritisation of low carbon solutions influences organisational culture, in the context of UK public sector FCRM construction. Through the implementation and development of a WLCPT a suitable context for a shift in practice will be tested; this cannot be defined by physical sciences (Saunders, 2009). This research has been positioned towards an interpretivist stance, which is an attempt to make sense of the world around us and is appropriate; in the organisational behaviour field and within complex adaptive systems, whereby activities undertaken or the behaviours of individuals or organisations (agents), learn or adapt to interactions with other agents (Holland, 2014). As a leading public sector organisation, EA will form the source of the research study area, the existing structure and the governance arrangements can be used to better understand and explain what is happening.

4.5 Research approach

Saunders, et al. (2007) identified two main research approaches: deductive and inductive. The deductive approach works on the more general to the specific, whereby author starts with a theory and hypothesis and designs a research strategy to test the hypothesis, usually a yes or no answer. The inductive approach is about researching to create theory, whereby data collection and theory development is as a result of the data analysis. This research will take an inductive approach and takes its focus from the working title of the research not the existing theory. Therefore, according to Saunders, et al. (2007) it would be more appropriate to work inductively when researching into a topic that is new, is debatable and where there is little existing literature, this would build a theory based on analysis of data. This research will take an inductive approach, in relation to the research area within UK public sector FCRM construction.

In order to build theory based on the analysis of data, the initial process of establishing the research problem, aim and objectives and the design of the conceptual framework adopts a deductive approach; this is whereby questions raised may be statements or informed speculation about the topic that the researcher believes can be answered (University of Derby, 2018). The intended result of this research is 'construction of new knowledge on which new forms of action can be based', where by action 'contributes to knowledge and knowledge alters action', this acknowledges that both agent interaction and the schemas of these agents are critical in processes of change in the context of complexity theory (Phelps and Hase, 2002).

Vaishnavi and Kuechler (2004) state that all designs begin with awareness of a problem, the design research also known as 'improvement research'. This highlights the problem solving and performance improving nature of an activity. This research will study the current practice of UK public sector FCRM construction, it will develop knowledge about existing realities and perceptions to prioritising low carbon in UK public sector FCRM construction. Identifying the problem, the suggestions for the problem's solution are drawn from the empirical investigation and from the existing knowledge/theory base. This research has the opportunity to observe and track the success of the implementation of a WLCPT, and its effect on organisational change in prioritising low carbon in UK public sector FCRM construction. In the context of a CAS a time element is required in order to understand the effect of the setting up and rollout of the WLCPT. The activities undertaken to influence change are set and developed and the result is the implementation and evidencing of the utilisation of WLCPT within the organisation and project context (Holland, 2014).

4.6 Research strategy

Saunders, et al. (2007), details seven approaches in the third layer research strategy, these strategies are categorised: experiment; survey; case study; action research; grounded theory; ethnography and archival research. Each of these strategies provide a direction and a process by which research is conducted (Remenyi et al., 1998). A research strategy is directed by the researcher's questions and objectives, existing knowledge, time and physiological underpinning. There are several strategies that can be applied to this research. However, experiment designs are more rigid and structured to enable the research to be replicated (University of Derby, 2018), and they look at the relationships between two or more variables (Saunders et al., 2007). Experiments attempt to manipulate independent variables to observe their effect on dependent variables (Collis and Hussey, 2009) which is not applicable in this scenario. As discussed under philosophy and approach, this research is governed by the interpretivist stance and uses an inductive approach, with a deductive approach to assist in defining the research questions and objectives. Looking at the facts and the why, in terms of the research examples, they can often be at the opposite ends of the scale (Farrell et al., 2017). As part of the establishment of research questions and objectives a survey is being used, although surveys are not normally used in an inductive approach (Saunders, 2007). From the perspective of quantitative and qualitative research, quantitative looks at the analysis of numbers, establishing the what (Farrell et al., 2017).

Creswell identifies five main strategies for qualitative research: these are ethnography, grounded theory, case studies, phenomenological research and narrative research. Phenomenological and narrative research could be relevant to this research study as they are positioned more towards identifying human experiences and studying the lives of individuals. As is ethnography which requires the researcher to become a full member of the group being studied in order to understand the phenomenon being investigated (Collis and Hussey, 2009; Easterby-Smith, 2008). Most ethnographic studies involve extended participant observation and do not use data collection techniques which oversimplify the complexities of the everyday life (Saunders, 2009). However, rather than observation the activities undertaken by the author to influence a change in the learning of others is intended; making ethnography unsuitable. Grounded theory is a possible appropriate approach as it can be achieved through data collection; however, it is deemed to be unsuitable for this research method due to the need to first implement the WLCPT, before suitable data can be tested.

Utilisation of case study design requires extensive study of one or more individuals or cases in a real-life context; in order to draw clear conclusions about data, the number of cases are restricted. Action research, is a strategy concerned with addressing issues to find and implement solutions. This enables the researcher to be part of the organisation or case study that requires the solution, allows for collaboration between the topic organisation and the researcher. Grounded Theory uses inductive methods to predict and explain behaviour to build theory. Starting with data being collected from observation, theory and predictions being generated from that data and then testing those predictions. Ethnography is rooted in anthropology, which is the study of others from a detached point-of-view. It requires the researcher to be a part of the community or situation they are researching. Archival research allows for exploratory, explanatory or descriptive analysis of changes tracked over a long period of time, through data collection on existing data sets or archive documents. However, the accuracy and breadth of information available may be an issue for researchers relying solely on this type of secondary data (University of Derby, 2018).

Each of these approaches could be used within this research study. However, the use of a case study and grounded theory would require the implementation of a WLCPT to be fully in place to accurately reflect whether low carbon is being prioritised, rather than concerned with whether a new process has been implemented. The author's profession would allow access to archival data; however, the archival research approach would also not align with the aim and objectives of this research study. Action research, and ethnography offer possible opportunities to use the author's profession and role to make observations and implement changes to achieve the solution. However, ethnography requires the researcher to be unbiased and to take an observational approach to the research study (Britannica, 2017). As the authors profession and role is directly linked to the subject area an observational and unbiased approach is not necessarily possible as actions will be implemented by the author to influence the learning of others, ethnography is not the appropriate approach and action research will be taken forward.

4.7 Choice of method

Saunders (2009) notes three strategy choices: mono method; mixed method and multi method. Mono method focuses on either qualitative or quantitative research which is not appropriate for this study. Mixed method allows for the use of qualitative and quantitative methods. Multi method is where the researcher uses both quantitative and qualitative data but the researcher's outlook is rooted in only one of them (University of Derby, 2018). Based on the pragmatist epistemological undertaking and the theoretical perspective of being interpretivist in nature, the research is progressing a mixed methods approach utilising both quantitative and qualitative research. The quantitative nature of the research is focused solely on the establishment of research questions and objectives, discussed in 3.4.1. Epistemology is about addressing facts, what constitutes acceptable knowledge; there is existing acceptable knowledge that the infrastructure sector has been limited in its progress in lowering carbon (Farmer, 2016, HM Government, 2013a, HM Government, 2017a). As the intention is to focus on UK public sector

FCRM construction, a review of the current progress and position in reducing carbon is required; the use of a survey in this instance, being more relevant to a deductive approach was deemed most appropriate. Confirming the accepted knowledge for the specific part of the construction industry UK public sector FCRM construction it is important to establish whether it is reconfirming the current industry position.

Progressing this a step further Tashakkori and Teddlie (1998, quoted in Phelps and Hase 2002): 'differentiate between mixed method and mixed model research. Mixed methods combine quantitative and qualitative approaches in the methodology of the study (such as in data collection) while mixed model studies combine these two approaches across all phases of the research (such as conceptualisation, data collection, data analysis and inference)'. According to Phelps and Hase (2002), 'action research is inherently open to mixed methods and mixed models, with Greenwood and Levin (2000) stating: 'action research is inherently multimethod research... effective action research cannot accept on a prior limitation to one or another research modality'. A strong case can be made for the adoption of mixed methods in complexity-based research'.

Taking a mixed method and mixed model approach to this research the core assumption is to combine statistical trends (quantitative data) with stories and personal experiences (qualitative data). Through the utilisation of a survey and action research approach and the testing of hypotheses with quantitative and qualitative data and reflection is proposed; this collective strength provides a better understanding of the research problem (Creswell, 2015). For the remainder of this research, qualitative strategies are most appropriate, as this emphasises words rather than numbers, in the collection and analysis of data (Bryman and Bell, 2003).

According to Creswell (2015) there are three designs for mixed method design: a convergent design; an explanatory sequential design and an exploratory sequential design. In the case of this research an explanatory sequential design is selected, whereby the use of quantitative methods in the form of a survey is used and then quantitative methods to help explain results in more depth is taken forward.

The justification for taking forward a mixed method and mixed model research approach is due to one single method not being sufficient enough to gain a clear understanding of the problem. The aim of this research is to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). Understanding the current position of this specific industry first needs to be established and grounded as acceptable knowledge, this is done so using a quantitative method. This allows for: the efficient analysis of data; for the investigation of relationships within the data; examines probable causes and effects and can draw conclusions from a large number of people. However, it recognises that this approach provides a limited understanding of the context of the participants; it is largely researcher driven and does not record the words of the participants (Creswell, 2015). The use of qualitative research supports the interpretivism approach and allows for this largely social and behavioural research study to better detail the perspectives of individuals, where it is based on the views of the participants and allows for the participant' experiences to be understood in context. The disadvantages of such qualitative research are then limited as a mixed method approach is used (Creswell, 2015).

4.8 Time Horizon, techniques and procedures

The fifth layer in Saunders' onion (2017) focuses on time horizons, cross-sectional and longitudinal. Both of these time horizons will be utilised within this research approach, the cross-sectional approach will provide a moment in time as to the current level of prioritisation of low carbon in UK public sector FCRM construction, via a survey. Cross-sectional designs can use qualitative and quantitative research and they measure an aspect or behaviour of many groups or individuals and at a single point in time. Longitudinal designs can also use qualitative and quantitative research but they study events and behaviours using concentrated samples over a longer period (University of Derby, 2018). The longitudinal approach will provide the basis for action research in the implementation of a WLCPT within UK public sector FCRM construction. As this is time consuming and requires the researcher to be immersed in the social world being studied, it is confirmed that the author's profession is inside this natural setting and aims to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). The author has a key role in ensuring that the prioritisation of low carbon is achieved in this sector. Action research, is primarily designed to deal with a specific problem in a specific situation; as part of this search for a solution the strategy allows the researcher to be part of the organisation that requires the change. It allows for collaboration between the topic organisation and the researcher. The process of action research moves from a clear objective to diagnosis of the problem and generation of a list of actions to solve the problem (University of Derby, 2018). The author attempts to derive a theory from data, systematically gathered and analysed through the research process (Bryman, 2008). In conjunction with action research, this provides a more systematic and unbiased view, with its real-life context using multiple sources of evidence (Yin, 2009), which can be identified as the most suitable strategies for this research.

4.8.1 Techniques and procedures

Saunders' et al., (2007) final onion layer, covers all decisions and tools required at this final stage. This must fit in with the philosophies, philosophical stances, strategies, choices and time-horizons already fixed upon if valid results are to be created and withstand criticism (University of Derby, 2018). The method structure used for this enquiry is illustrated in Figure 4.1. This takes into account the 5 stages of the reflection spiral; the techniques and procedures are discussed in the following two sections, research techniques for data collection in Section 4.8.2 and research techniques for data analysis in Section 4.8.3.

4.8.2 Research techniques for data collection

In establishing the research techniques for this study, it needed to be recognised that not all of the study could be fully planned from the initial outset. This is in part due to the nature of the action research, the development of the intended approach and the responses received within the timeframe of the research study which requires reflective action in-order to provide an improvement for the researcher and the intended outcome of the study. Denzin and Lincoln (1994) describe this approach as 'Bricoleur': 'The qualitative researcher – as -bricoleur uses tools of his or her methodological trade, deploying whatever strategies, methods, or empirical materials as are at hand (Becker 1989). If new tools have to be invented, or pieced together, then the researcher will do this. The choice of which tools to use, which research practices to employ, is not set in advance. The 'choice of research practices depends on the questions that are asked, and the questions depend on their context' (Nelson et al., 1992), what is available in the context, and what the researcher can do in the setting'.

The research techniques identified in this study are a survey and action research. The survey is conducted at the start of the research to baseline current organisational culture and perception in regards to low carbon. The survey is utilised to direct the activities to be undertaken within the action research phase. The action research approach will provide access to information that the author has either directly or indirectly delivered (through others) on behalf of the organisation. Data from both research methods are utilised to test the hypotheses, and complete the following objectives; Table 3.1 provides a further breakdown.

Table 4.1 Objective, Hypotheses and Model

Objective (OB)	**Hypothesis (H)**	**Model**
OB1: To investigate whether demography of participants influences low carbon prioritisation	H1: The demography of participants influences low carbon prioritisation	Main survey
OB2: To investigate whether organisational change influences low carbon prioritisation	H2: The level of organisational change influences low carbon prioritisation	Main survey
OB3: To investigate whether organisational carbon leadership influences low carbon prioritisation	H3: The level of organisational carbon leadership influences low carbon prioritisation	Main survey
OB4: To investigate whether quality of training influences low carbon prioritisation	H4: The quality of training influences low carbon prioritisation	Main survey
OB5: To investigate whether organisational culture influences low carbon prioritisation	H5: The level of organisational culture influence low carbon prioritisation	Main survey
OB6: To investigate whether tonne of carbon influences cost	H6: The tonne of carbon influences cost	Action Research
OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influence tonne of carbon	H7: The level of implementation the quality of implementation of a whole life carbon planning tool influence tonne of carbon	Action Research
OB8: To investigate whether type of training influences tonne of carbon	H8: The type of training influences tonne of carbon	Action Research
OB9: To investigate whether low carbon promotion influences organisational culture.	H9: The level of low carbon promotion influences organisational culture	Action Research

4.8.3 Research techniques for data analysis

The research analysis will be undertaken in two parts; the survey and the action research. The survey analysis uses a traditional quantitative approach, the findings of which will be used to inform the start of the actions taken forward into the action research activities. The analysis from the action research activities uses the method of qualitative analysis and the action research spiral of self- reflection and testing of data produced via the implementation of a WLCPT to test against the hypotheses identified using a traditional quantitative approach.

4.9 Thesis write-up

This research write-up commenced during the initial stages of the literature review and has been continually updated as the research has progressed reflecting any new findings. Once the survey data analysis was complete and the funding request authorised for a new WLCPT, an initial plan for implementation took place. The framework for the research method has been explained throughout this chapter using Saunders' research onion (2009). This approach alone is insufficient to ensure quality research is produced, therefore the following chapters, outline the approach the author has taken to maximise the validity of the research.

4.10 Establishing the quality of research

Utilising a mixed method and mixed model approach the quality of the research needs to be maintained and managed as a key output from this quantitative and action research approach. Identifying the procedures to ensure accuracy and credibility of the findings are according to McNiff and Whitehead (2011) essential when taking an action research approach.

4.10.1 Validity and legitimacy of author's knowledge claims

According to Yin (2009) it is about using appropriate measures for concepts being studied, and as such constructing validity mainly relates to the data collection phase and maintaining a chain of evidence within the research in order to achieve a quality result. Validity is about establishing the truth, legitimacy is regarded as acceptance in the public sphere (McNiff, 2011). For this mixed method and mixed model approach; the systematically gathered and analysed data is in the form of a qualitative survey and action research activities tested against hypotheses.

4.10.2 Validating of author's knowledge claims

Within action research there are different approaches to testing validity; the most common are as follows (McNiff, 2011):

- catalytic validity – this term, coined by Patti Lather in 1991, expresses the idea that the experience of a study would enable people to move to new, more productive positions;
- construct validity – refers to the idea that researchers already have ideas and models (constructs) about the topic being studied. It is therefore important to use multiple ways of establishing that what they are investigating really is going on, and not just them imposing their existing constructs on the reality they are observing;
- face validity – the researcher does not take things simply at face value but interrogates underlying assumptions;
- rhizomatic validity – refers to the interconnected nature of human enquiry and the power of a study to have influence in multiple directions.

In addition to this, it is important to establish quality in self-study action research and demonstrate validity grounded in the researcher's ontological values, whilst also actively seeking out critique and validating knowledge claims.

4.10.3 Legitimacy of authors' knowledge claim

Establishing legitimacy for knowledge claims can be undertaken, through recognition by the community of practitioners or the community of researchers. An editorial in the Action Research Journal (Brydon-Miller et al., 2003) stated that 'Action research has a complex history because it is not a single academic discipline but an approach to research that has emerged over time from a broad range of fields'; 'what links them is the key question of how we go about generating knowledge that is both valid and vital to the wellbeing of individuals, communities, and for the promotion of larger-scale democratic social change'. Despite this recognition Brydon-Miller et al., (2003) also recognise that 'one of the weaknesses of action research is its localism and the difficulty in intervening in large-scale social change efforts'. Within the scope of this study the local Action 1: implementation of a WLCPT is balanced by the Action 2: promotion, prioritisation and implementation of low carbon solutions; which looks to test the wider large-scale social change efforts. This approach provides a framework for also establishing legitimacy for knowledge claims within the public arena.

4.10.3.1 Community of practitioners

A researchers' (author) learning can become an account of what has been done, to show how individuals have learned to do things differently and better. Alternatively, the learning of others in the workplace can be shown, by accessing their work so professional communities can see how they can apply something similar. Researchers' (the author) act as agents, to show how they have changed the rules by changing their practice (McNiff, 2011).

4.10.3.2 Community of researchers

For an 'action researcher your work as an intellectual and a practitioner is integrated, you are a thinker and a doer all the time' (McNiff, 2011). Establishing legitimacy for authors' knowledge as part of a community of researchers can be undertaken by showing the validity of their work. In addition to this it is persuading intellectuals, the large bodies of evidence that go a long way to influencing public opinion and to persuading others to adopt similar practices (McNiff, 2011).

4.11 Survey method

The study aim is to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). When researching a subject area that is contentious and has limited literature, the most appropriate way to undertake research is via an inductive approach by collecting data and developing a theory as a result of the data analysis (Saunders et al., 2007). The initial literature review identified several gaps in the contributions made, therefore the justification for the survey and purpose of questions was to clarify the current approach to low carbon reduction within UK public sector FCRM construction. Alternative research methods were explored at early stages; the use of interviews and ethnography were considered and discounted. The reasoning for this were the extent of roles and responsibilities of both public and private sector individuals across a project lifecycle, would have necessitated multiple interviews, to ascertain a balanced response. Which presented, accessibility and resource issues and would have resulted in a lack of independent and unbiased data. To this end the initial research approach was progressed in the form of a quantitative survey following principles outline by Farrell et al., (2017), and an initial pilot survey was undertaken, it included a broad range of initiatives being progressed by UK Government.

4.11.1 Pilot survey

In order to test the appetite for change and in particular the prioritisation of a low carbon in UK public sector FCRM projects, a pilot survey has been undertaken to focus on the areas of low carbon, efficiency, and Building Information Modelling (BIM). A quantitative approach was used to obtain results which may be inferred to reflect the whole of the population. The questionnaire comprised of 33 questions, which include both quantitative and qualitative answers, and was divided into three main themes: (i) background information, (ii) organisational culture and organisational leadership, and (iii) low carbon initiatives. It had been designed to meet OB1, OB2, OB3, OB4, OB5, OB6 and OB9, to gain an insight as to whether it is public or private sector organisations leading on low carbon initiatives. Questions were developed based on issues in the literature, this comparison can be found in Table 4.2, which provides a breakdown of how the literature review and research objectives are linked to the pilot survey questions. The inclusion of a qualitative narrative had been undertaken to assist the individuals in responding to the implementation of new initiatives and their response to change.

Table 4.2 Pilot survey questions relating to objectives and literature

Literature subject	Objective (OB)	Pilot survey question (Appendix B)
Demography of professional	OB1	Q1; Q2; Q3; Q4; Q5
Organisational change	OB2	Q20, Q24, Q25, Q26, Q28
Organisational Carbon Leadership	OB3	Q10
Quality of Training	OB4	Q18, Q19, Q23
Organisational culture	OB5	Q6, Q7, Q15, Q17, Q21, Q22, Q27, Q33
Low carbon prioritisation	OB1, OB2, OB3, OB4, and OB5	Q8, Q9, Q11, Q12, Q13, Q14, Q19, Q23, Q29, Q30, Q31
Cost	OB6	Q16, Q32
Whole life carbon planning tool	OB7	N/A
Type of training	OB8	N/A
Low carbon promotion	OB9	N/A

4.11.2 Main survey

The pilot survey provided clarity and focus for further research, along with refinement required for the main survey. Questions included: demography of professionals; organisational culture and leadership; low carbon and changing behaviours. The main survey was constructed to test current thinking; the hypotheses and to supporting the action research actions. Comprising of the following subject areas: demography of professionals (OB1); organisational culture (OB5) and organisational carbon leadership (OB3); low carbon (OB1— 5) and change (OB2). Demography of professionals' questions requested information on whether respondents were employed in the public or private sector, their gender, age, duration in work and the role they undertook on FCRM construction projects. UK public sector FCRM organisations have been identified as key respondents in low carbon construction, primarily as the role of client. The private sector often undertakes the role of designer or contractor. Within the main survey questions on organisational culture and leadership focused on the 'hearts and minds element', with questions teasing out the level of importance and satisfaction individuals felt about low carbon individually. How they perceive their organisations respond to low carbon construction, who lead on this and how active their organisation is in embedding low carbon. Low carbon questions specifically focus on how low carbon solutions, calculations and cost to compare against each other, along with the level of training received. Changing behaviours focused on assurance, incentivisation, reporting and how individuals respond to change. Table

4.3 provides a breakdown of how the literature review and research objectives are linked to the survey questions.

The survey population were project teams from a leading UK public sector government organisation undertaking FCRM construction projects; the sample was a specific delivery unit within the department. The selection of project teams delivering construction projects provided a cross section of stages in the project life cycle, ranging from pipeline, appraisal, design, construction and post construction. The survey looked at establishing whether low carbon is successfully understood and embedded into UK public sector FCRM construction; whether there has been sufficient prioritisation and promotion of low carbon and to establish whether the importance of low carbon has been fully realised.

Table 4.3 Main survey questions relating to objectives and literature

Literature subject	Objective (OB)	Main survey question (Appendix D)
Demography of professional	OB1	Q1; Q2; Q3; Q4; Q5
Organisational change	OB2	Q16, Q17, Q18, Q19, Q20
Organisational carbon leadership	OB3	Q9, Q21
Quality of Training	OB4	Q15
Organisational culture	OB5	Q6, Q7, Q8, Q10
Low carbon prioritisation	OB1, OB2, OB3, OB4, and OB5	Q11, Q12, Q13
Cost	OB6	Q14, Q22
Whole life carbon planning tool	OB7	N/A
Type of training	OB8	N/A
Low carbon promotion	OB9	N/A

Having identified gaps in the existing body of knowledge, through the initial review, the next step was to carry out a more detailed and specific review on the following concepts as covered within the survey. Low carbon prioritisation, implementation and promotion; this included:

- the role of organisational culture;
- implementing change;

- where in the project life cycle, low carbon was actively discussed by teams in comparison to cost?
- the response to training, best practice and lessons learnt initiatives;
- whether low carbon solutions lead to reduced cost in FCRM.

The review remained an on-going process requiring refinement and modification as the study progressed. The survey resulted in adjustments and direction for the main body of the research (Easterby-Smith, 2008).

4.12 Action research method

Action research method is based on the continued improvement approach as identified within the research spiral (Research Methodology, 2018). Table 4.4 provides a breakdown of how the literature review and research objectives are linked to the action research activities. Further details are provided in Chapter 5.

Table 4.4 Action research activities relating to objectives and literature

	A	B	C
1	**Literature subject**	**Objective (OB)**	**Action research outputs**
2	Demography of professional	OB1	N/A
3	Organisational change	OB2	Action 2: Capital carbon maturity review
4	Organisational carbon leadership	OB3	Action 2: Capital carbon maturity review and Research practitioner feedback
5	Quality of training	OB4	Incorporated into OB8
6	Organisational culture	OB5	Action 2: Research practitioner feedback
7	Low carbon prioritisation	OB1 - 5	Action 1: reported outputs
8	Cost	OB6	Action 1 reported outputs
9	Whole life carbon planning tool	OB7	Action 1: implementation of WLCPT
10	Type of training	OB8	Action 1: WLCPT e-learning and reported outputs
11	Low carbon promotion	OB9	Action 2: Promotion activities

4.13 Research ethics

The researcher was careful to follow the University of Bolton ethical protocols (UoB, 2006) and as described by Farrell et al (2017). The University RE1 form was completed and approved as detailed in Appendix L. Permission to undertake the research was sought from the author's employer.

When undertaking and action research approach within your own organisation as clear distinction is identified, on which Alder and Alder (1987) describe as being a ‘complete member’ in which you are a full member of the organisation, and wanting to remain in their desired career path once the research has completed, taking forward the opportunity to acquire ‘understanding in use’ rather than ‘reconstructed understanding’ (Coghlan, 2014). The challenge is to create a community of inquiry within the organisation from the collaboration of practitioners and author (Coghlan and Shani, 2008), whilst also distinguishing between the ‘researcher (author) and the system in and on which the action research is taking place’ (Coghlan, 2014). When focusing on the researcher and the system (organisation) the balance of intended self-study in action and from and individual and system perspective needs to be clarified. For the purposes of this study ‘both the researcher and the system are engaged and intended study-in-action’. The ‘system has made or is making a commitment to change’ and the ‘researcher’s role involves being part of the collective reflection on experience and articulating what is happening’ (Coghlan, 2014).

Ethical issues within action research whereby the researcher (author) involves participants in planning the research and processing the results, can become more challenging and requires the researcher’s self-understanding and social vision, requiring ethical behaviour in which a researcher must engage in the democratic, participative values that the action research is grounded (Coghlan, 2014). William and Prosser (2002) pose three ethical questions that have been referred to as part of this study, with mitigations put in place as part of the evidencing.

- question 1 – If researchers and participants collaborate closely, how can confidentiality and anonymity be preserved?
- question 2 – If action research is a ‘journey’ and ‘evolves’, how can informed consent be meaningful?

- question 3 – As action research can have political consequences, how can action researchers avoid doing harm to participants?

In addressing these questions, the following measures have been put in place:

- all data utilised for analysis has been anonymised;
- all opinions provided, excluding the authors own interpretation has been provided in confidence and only explicitly shared with the permission on the participant (Chapter 8 Section 8.5 to 8.5.3);
- the evidence of the organisations maturing carbon journey has been publicly verified and shared as part of the ongoing process, where possible information utilised is pre shared as part of the internal organisation reporting (inclusive of supplier updates) and therefore is deemed non confidential in nature;
- the findings of this research are owned by both the researcher (author) and the organisation, the data utilised in primary for the survey and secondary for the action research process; the analysis and reflection of which has been solely undertaken by the author.

In addition to the above measures undertaken, the issue of ethics in action have also primarily been addressed through the action research cycle itself with ethical questions posed as part of the action research spiral, in planning action and reflection, taking into account who and how users or teams will be affected as part of the next implemented continuous improvement cycle (Coghlan and Brannick, 2008, Gellerman et al., 1990, Walker and Haslett, 2002).

4.14 Summary and link

This chapter has provided an insight to and justifies the research method, from the author's area of interest, available literature through to the research problem and approach following research 'onion' (Saunders et al., 2007), in regards to data collection and analysis. The method os outlined through the research philosopy, strategy, choice, time horizon and techniques. The research methods are justified; this study applies interpretivism perspective and theoretical underpinning. The main aim of this research is to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). A mixed model and mixed method approach in the form of a quantitative survey and action research approach were selected as the preferred research strategy, along with the rationale for selection. The research methods were detailed, outlining the limitations and challenges with both approaches. Chapter 5 presents the action research continued improvement method.

CHAPTER 5: UPDATED CONCEPTUAL FRAMEWORK

5.1 Introduction

Chapter 4 illustrated the research methodology; this chapter builds upon Chapter 3 and refines the initial conceptual framework based upon the findings from the survey undertaken and covers the following areas:

- key concepts;
- development of key concepts for action research;
- planned action;
- updated conceptual framework;
- the chapter is summarised.

5.2 A conceptual framework in action research

Section 3.2 outlined the importance and relevance of a conceptual framework, the sequences identified as part of the action research spiral Figure 3.1, are implemented as part of this study and are outlined in Chapter 6. Kemmis (2018) states ‘participatory action research (PAR) is a way of working which helps teachers, students and communities to work individually and collectively in developing their practices, their understandings of their practices, and the situations in which they live and work – to transform the work, the worker and the workplace’. Researcher in creating knowledge and produces accounts that contains descriptions of research (what was done) and explanations (why it was done and what was aimed for) (McNiff, 2011). To be both theoretically and practically useful, to better understand prioritisation of low carbon in UK public sector FCRM construction, for the application of complexity theory in organisational contexts (Phelps and Hase, 2002; Lissack, 1999).

5.3 Development of key concepts for action research

Having progressed this study with the aim to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT); the initial planned traditional approach was to undertake a survey and case studies to develop and test the hypotheses. However, the approach did not fully address the issue of improvement for the organisation in which the author was employed. The author took the steps to review the current systems and approach within the organisation for carbon and proposed an alternative way forward.

This process in itself offered the opportunity to change the author's approach to that of action research. In developing the key concepts and research techniques for data collection, a requirement of self-reflection and observation of the authors working environment and practices was undertaken, resulting in the following statements and questions being asked by author:

- key concept 1 - role of UK public sector FCRM clients in reducing carbon within construction, where teams are empowered to make low carbon decisions:
    - question: what is the current status on carbon within UK Public Section FCRM construction and what role does the organisation play?
    - OB1: to investigate whether demography of professionals influences low carbon prioritisation;
    - question: can low carbon initiatives (including tools) influence the organisation and wider construction industry?
    - OB2: to investigate whether organisational change influences low carbon prioritisation;
    - OB3: to investigate whether organisational carbon leadership influences low carbon prioritisation;
    - OB4: to investigate whether quality of training influences low carbon prioritisation;
- key concept 2 - increased climate change challenge and need for greater action across industry:
    - question: what can people do to mitigate climate change to protect the planet for future generations, within a work environment?
    - OB5: to investigate whether organisational culture influences low carbon prioritisation;
- key concept 3 - need for empowering project teams within FCRM construction to reduce carbon.
    - question: costs are driving project decisions; how can project teams be empowered and up-skilled to reduce carbon?

- OB6: to investigate whether tonne of carbon influences cost;
- OB7: to investigate whether the quality of implementation of a whole life carbon planning tool influences cost;
- OB8: to investigate whether type of training influences tonne of carbon;
- OB9: to investigate whether low carbon promotion influences organisational culture.

Further detail on 'Key concepts - What are the authors' concerns?' can be found in Appendix A.

5.4 Planned action

In identifying the key concepts and how these relate to the authors' concerns in the concept of action research; a conceptual framework for planned action was created in order to progress current thinking and to further narrow down the action areas to be taken forward. Findings from the main survey identified organisational change, organisational culture and quality of training influenced low carbon prioritisation. However, organisational carbon leadership did not influence low carbon prioritisation. The lack of clarity on who leads in this area is in contradiction to the evidence identified within the literature review, further details on the survey analysis can be found in Chapter 7. In narrowing down the concept the following action areas had been identified:

- action 1: implementation of a WLCPT and supportive training;
- action 2: prioritisation, implementation and promotion of low carbon solutions.

The actions identified look to improve or refocus the current status of low carbon prioritisation refined by the survey findings which provide a specific understanding of maturity within UK Public sector FCRM at a specific point in time. The study therefore is limited to UK public sector FCRM construction and examines how a leading government organisation can be empowered to make a positive cultural change to support low carbon prioritisation. Supporting the study aim to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT).

5.5 Updated conceptual framework

The initial conceptual framework of the study is presented in Figure 3.2, this has been refined following the survey findings Figure 5.1 ‘Conceptual framework’ sets out how the organisational line of sight, aligns to the author’s key concepts and actions, these original figures were created by author as part of the capital carbon maturity review (2019a) and updated to reflect the research study.

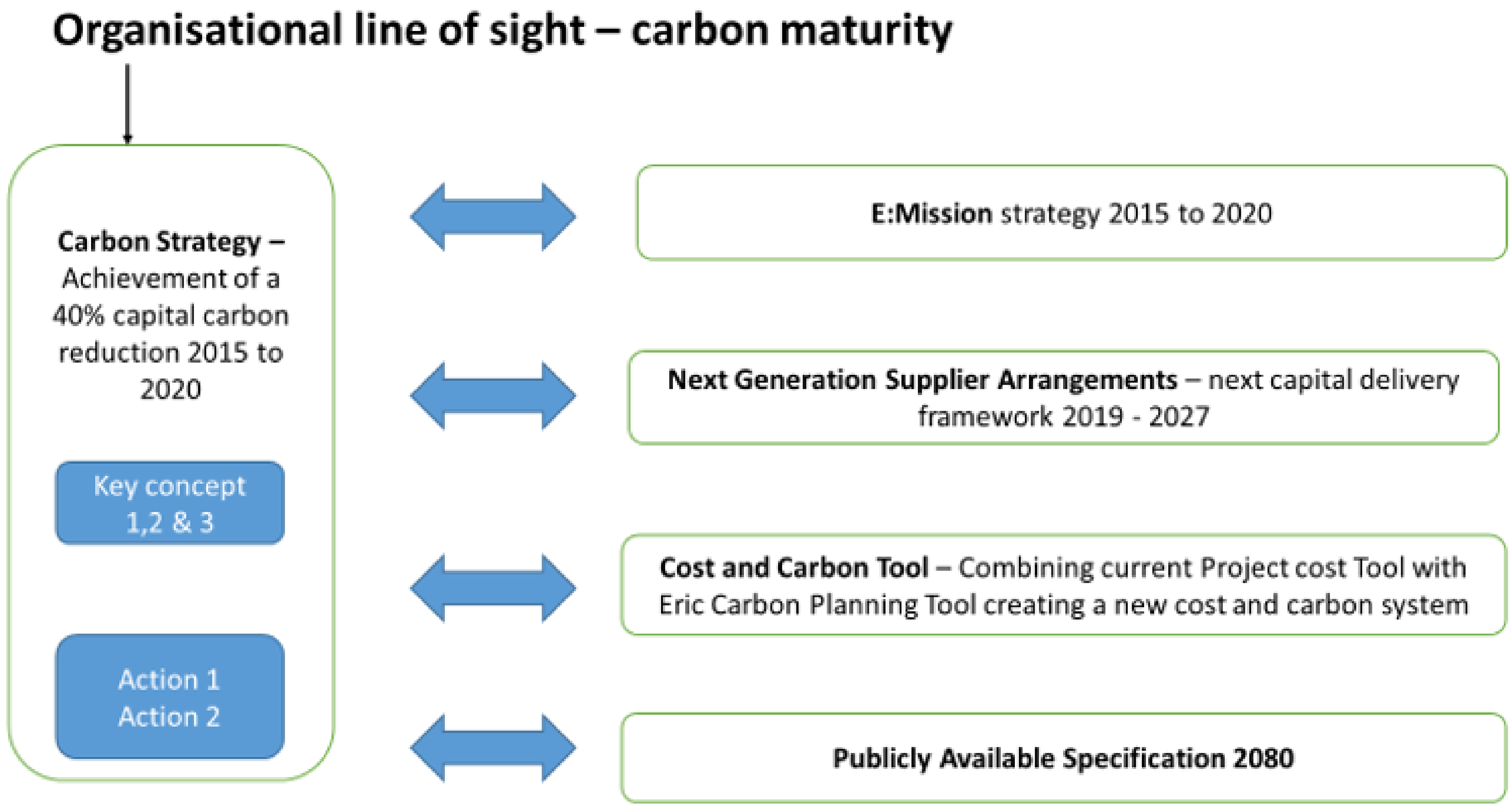


Figure 5.1 Conceptual Framework – organisational line of sight – carbon maturity (EA, 2019g)

5.6 Summary and link

This chapter has elaborated on the process for a conceptual framework and illustrates how this can support an action research approach. It is developed based on literature and the author's own observations and illustrates the process for achieving the research objectives, thus:

- OB1: to investigate whether demography of professionals influences low carbon prioritisation
- OB2: to investigate whether organisational change influences low carbon prioritisation
- OB3: to investigate whether organisational carbon leadership influences low carbon prioritisation
- OB4: to investigate whether quality of training influences low carbon prioritisation
- OB5: to investigate whether organisational culture influences low carbon prioritisation
- OB6: to investigate whether tonne of carbon influences cost
- OB7: to investigate whether the quality of implementation of a whole life carbon planning tool influences cost
- OB8: to investigate whether type of training influences tonne of carbon
- OB9: to investigate whether low carbon promotion influences organisational culture.

Chapter 6 will look to develop a conceptual framework through an action research approach to effect a paradigm shift in practice and improved low carbon prioritisation, in the effort to search for new knowledge.

CHAPTER 6: RESEARCH METHOD – ACTION RESEARCH

6.1 Introduction

Coghlan (2008) describes action research authenticity as the characterisation of four process imperatives:

- be attentive (to the data);
- be intelligent (in inquiry);
- be reasonable (in making judgements);
- be responsible (in making decisions and taking action).

These ‘process’ issues focus on how research practitioners (the author) engage their action research and are ‘imperative’ in that they focus on what ought to be (Coghlan, 2008). Utilising the results from the main survey, the literature review and key concepts (further outlined in Chapter 6), the main actions identified provide the focus to examine the organisations’ current position in regards to organisational culture, low carbon promotion, cost and carbon alignment, and contribution to knowledge, through research in action; collaborative democratic partnership and evidencing a sequence of events and approach to problem solving.

6.2 Review of approach

In commencing this research study, the author’s overall aim for this work was to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). The former government target of 80% reduction by 2050 (HM Government, 2016), has through the progress of this study, changed and become more challenging with the need to achieve net zero by 2050 (HM Government, 2019g). This study will contribution to the organisations’ carbon targets and in turn will further evidence governments’ progress through the implementation of a WLCPT and supporting documents and processes.

The path this research study has taken, started as one of a traditional quantitative approach comprising of questionnaire and case studies, to that of a mixed method and mixed model approach via questionnaire and action research. This was primarily due to the nature of the research being undertaken and progressed, along with circumstances that arose during the progression of the study. The initial research plan had a clear if somewhat optimistic timescale. Identifying the following research objectives, further details can be found in Figure 6.1:

- initial OB1: To determine whether cultural factors influence the prioritisation of Low Carbon in the UK public sector FCRM construction industry;
- initial OB2: To determine whether organisational leadership influences the prioritisation of low carbon in the UK public sector FCRM construction industry;
- initial OB3: To determine whether the prioritisation of low carbon reduces costs within the UK public sector FCRM construction industry, utilising the Environment Agency's carbon calculator.

The opportunity to replace the existing carbon calculator was undertaken with support and financial backing from the author's organisation. Over a seven-month timescale, the author submitted and secured project funding, scoped project objectives, completed and sent out the tenders, reviewed and assessed the returns and awarded the contract. The programme of works was undertaken in a tight but achievable three-month timescale, project managed by the author. An internal organisation and supplier working group was set up and representatives from the project delivery team, FCRM Area leads, Internal Environment Management (IEM) team and Water and Environment Management (WEM) supply chain represented a cross section of future users of the tool.

This work formed part of the organisation's e:Mission 2015 – 2020 plan of which carbon reduction strongly featured; this was rolled out in April 2015. The delivery of the new WLCPT was also rolled out in the same month. The research approach then became more about the author and her direct role in implementation and testing of the WLCPT and associated challenges this represented in the context of organisational change and culture.

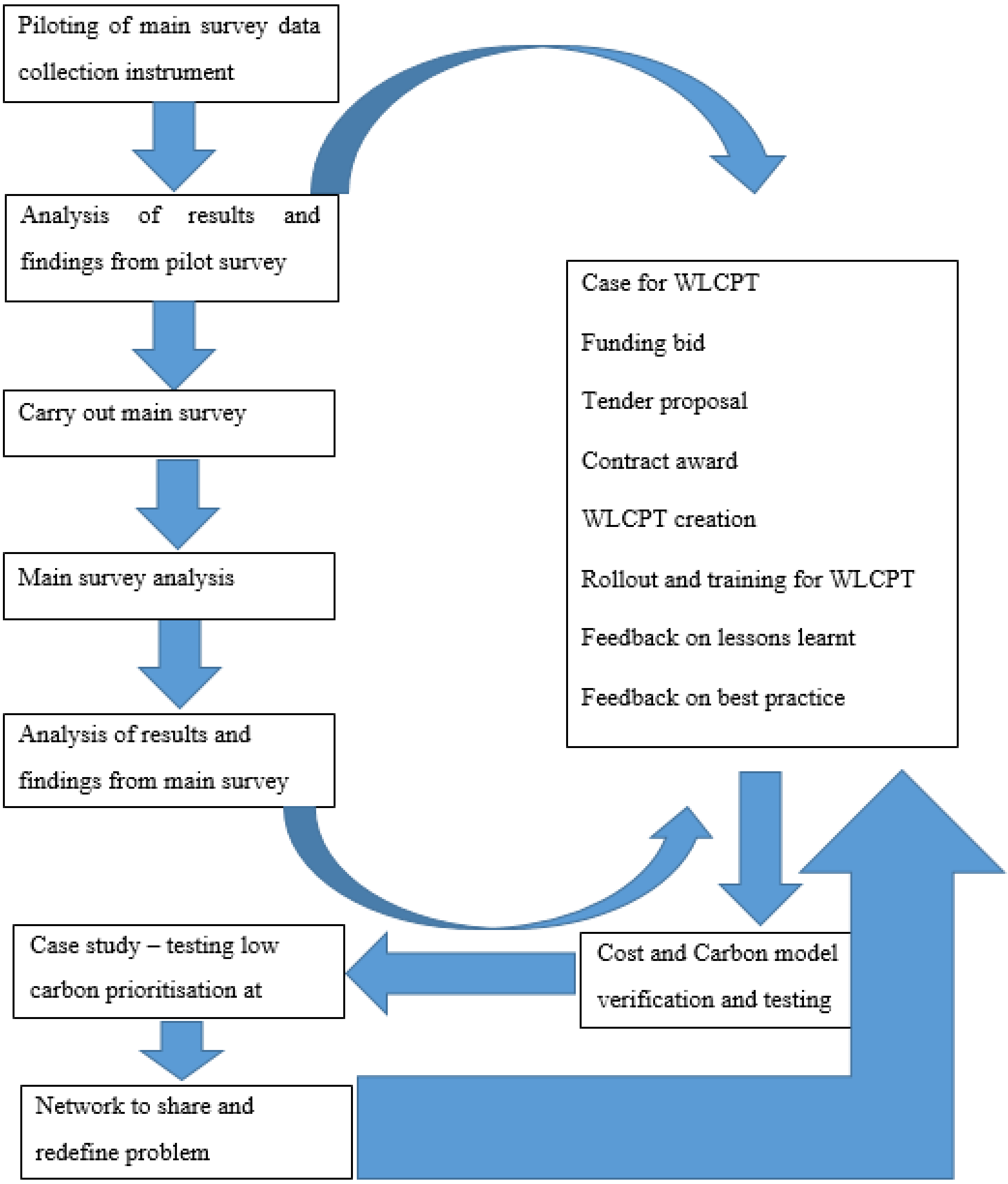


Figure 6.1 Activities from initial research plan

6.3 Review of objectives

With the implementation of the e:Mission 2015-2020 plan and the rollout of the WLCPT, a planned series of face-to-face sessions, WebEx meetings, papers and communications were implemented. This was to get teams and suppliers up to speed on the new tool and the reasons behind the chosen changes and how these supported the organisation's plan. From April 2015 to May 2016 the organisation's impetus was in ensuring that all relevant users were aware of the change and implemented the required changes. It is during this time the author had no direct involvement within the WLCPT (from June 2015 to November 2015); upon returning to the project the realisation that the anticipated impact the WLCPT had not been fulfilled.

It is at this point that the sheer scale of the challenge became evident. Initial OB1: To determine whether cultural factors influence the prioritisation of low carbon in the UK public sector FCRM construction industry. Whereby the possible correlation between variables, may not be achievable due to the low level of WLCPT implementation. The year 2015-2016 reporting results showed a clear lack of uptake and implementation of the WLCPT. Activities undertaken to mitigate this were in the form of primarily supplier lead training sessions, with client lead promotion via the Internal Environment Management team (IEM, which was renamed Sustainable Business team in 2018) and the FCRM Steering Group. The lack of internal ownership and soft launch significantly affected the intended prioritisation, promotion and implementation of the WLCPT.

It also significantly affected the testing of initial OB2: To determine whether organisational leadership influences the prioritisation of low carbon in the UK public sector FCRM construction industry. At this point leadership was inconsistent across the organisation; although the FCRM Steering Group was avidly championing the use of the new tool and carbon reduction as a whole, the key priority across FCRM was the safeguarding from flooding of 300,000 houses. Leadership within the main FCRM Areas and Programme and Contract Management (PCM, formerly National Capital Programme Management Service, (NCPMS) delivery team was supportive, but not expressly supported or encouraged at all management levels. To sufficiently test whether organisational leadership influences prioritisation of low carbon in the UK public sector FCRM construction industry, evidence of activity would need to be keenly present in order for initial OB2 to be substantiated.

In questioning this status, it was evident that there was still a substantial lack of awareness of the WLCPT, its intended purpose and the link to wider government objectives. The standard opinion that low carbon solutions were more costly was a regular conversation although not supported by evidence. The sheer lack of utilisation of the WLCPT made the possible testing of initial OB3: To determine whether the prioritisation of low carbon reduces costs within the UK public sector FCRM construction industry, utilising the EA's carbon calculator, was unachievable. This resulted in a lack of data available to test if low carbon results influence low costs in UK public sector FCRM construction.

In drawing out the change from the traditional research approach to that of an action research approach, the proposed research objectives also needed to be reviewed. Having taken into account the principles of action research and the initial objectives the author started out wanting to test within this study; the identification of these concepts within the literature review (3.3.1) and survey results (covered later in Chapter 7), better enabled the key concepts to be further developed with an action research approach (5.3). By questioning what the author and the organisation could do to affect a required change through planned action (5.5), the following action research activities were identified:

- action 1: implementation of a WLCPT and supportive training
- action 2: prioritisation, implementation and promotion of low carbon solutions

Utilising these actions to testing of the following revised research objectives, has been achieved via a questionnaire and action research approach. The new research questions (RQ), objectives (OB), hypotheses (H) and variables (VAR) are as per the areas outlined in Chapter 1 Table 1.1 and Table 6.1. Table 6.2 outlines which model and method has be used to evidence each VAR.

Action research is a sequence of self-reflective cycles; the spiral can be seen in Figure 3.1, in Chapter 3 Initial conceptual framework. The five sequences of the spiral will be followed for the remainder of this chapter to structure the action research approach and to demonstrate how action 1 and action 2 have been utilised to achieve the research objectives. The final sequence of the spiral ‘Reflection’ for each action will be covered in Chapter 9. In engaging with this action research approach, the two main action areas were determined and taken forward (Coghlan, 2008).

Table 6.1 Research questions, objectives, hypotheses, variables and unit of measure (Table 1.1)

Research Question (RQ)	Objective (OB)	Hypothesis (H)	Variables (VAR) and Unit of measure (UofM)	
RQ1: Does demography of professional influence low carbon prioritisation?	OB1: To investigate whether demography of professionals influences low carbon prioritisation	H1: The demography of professionals influences low carbon prioritisation	VAR 1 demography of professionals, UofM sector, gender, age, experience and role.	VAR 2 low carbon prioritisation, UofM 0 - 100%
RQ2: Does organisational change influence low carbon prioritisation?	OB2: To investigate whether organisational change influences low carbon prioritisation	H2: The level of organisational change influences low carbon prioritisation	VAR 3 organisational change, UofM 0 - 100%	
RQ3: Does organisational carbon leadership influence low carbon prioritisation?	OB3: To investigate whether organisational carbon leadership influences low carbon prioritisation	H3: The level of organisational carbon leadership influences low carbon prioritisation	VAR 4 organisational carbon leadership, UofM 0 - 100%	
RQ4: Does quality of training influence low carbon prioritisation?	OB4: To investigate whether quality of training influences low carbon prioritisation	H4: The quality of training influences low carbon prioritisation	VAR 5 quality of training, UofM 0 - 100%	
RQ5: Does organisational culture influence low carbon prioritisation?	OB5: To investigate whether organisational culture influences low carbon prioritisation	H5: The level of organisational culture influence low carbon prioritisation	VAR 6 organisational culture, UofM 0 - 100%	
RQ6: Does tonne of carbon influence cost?	OB6: To investigate whether tonne of carbon influences cost	H6: The tonne of carbon influences cost	VAR 8 tonne of carbon, UofM unit tonne of carbon	VAR 7 cost, UofM pound sterling (£)
RQ7: Does the quality of implementation of a whole life carbon planning tool influence tonne of carbon?	OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influences tonne of carbon	H7: The level of implementation the quality of implementation of a whole life carbon planning tool influence tonne of carbon	VAR 9 quality of implementation of a whole life carbon planning tool, UofM 0 - 100%	VAR 8 tonne of carbon, UofM unit tonne of carbon
RQ8: Does type of training influence tonne of carbon	OB8: To investigate whether type of training influences tonne of carbon	H8: The type of training influences tonne of carbon	VAR 10 type of training, UofM 0 - 100%	
RQ9: Does low carbon promotion influence organisational culture?	OB9: To investigate whether low carbon promotion influences organisational culture.	H9: The level of low carbon promotion influences organisational culture	VAR 11 low carbon promotion, UofM 0 - 100%	VAR 6 organisational culture, UofM 0 - 100%

Table 6.2 Model and Method utilised

VAR	Model main survey or action research	Method qualitative or quantitative	Questions or Activity
VAR 1 demography of professionals	Main survey	Quantitative	Questions 1 to 5
VAR 2 low carbon prioritisation	Main survey	Quantitative	Questions 11, 12 and 13
VAR 3 organisational change	Main survey	Quantitative	Questions 16 to 20
VAR 4 organisational carbon leadership	Main survey	Quantitative	Question 9 and 21
VAR 5 quality of training	Main Survey	Quantitative	Question 15
VAR 6 organisational culture	Main survey	Quantitative	Questions 6, to 8 and 10
	Action research	Qualitative	Action 2: Capital carbon Maturity Review
VAR 7 cost	Main survey	Quantitative	Question 14 and 23
	Action research	Quantitative	Action 1: data from projects that have both a cost and carbon submission at the end of the project
VAR 8 tonne of carbon	Action research	Quantitative	Action 1: tonne of carbon outputs from WLCPT
VAR 9 quality of implementation of a whole life carbon planning tool	Action research	Quantitative	Action 1: number of carbon data and reports submitted
VAR 10 type of training	Action research	Quantitative	Action 1: comprise of; the number of project managers who have completed the e-learning module; submitted a carbon return at the end of the project and applied low carbon best practice approaches
VAR 10 low carbon promotion	Action research	Qualitative	Action 2: wider awareness raising and publicising activities undertaken by the research practitioner and assessment of the organisation's capital carbon journey and alignment to PAS 2080

6.4 Action 1: Implementation of a WLCPT and supportive training

The activities undertaken through the implementation of a WLCPT and the supportive training will be used for, OB6: To investigate whether tonne of carbon influences cost; OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influence tonne of carbon and OB8: To investigate whether type of training influences tonne of carbon.

The analysis in whether these objectives can be achieved will be covered within Chapter 8. From the survey analysis and literature review the provision of a WLCPT, along with supportive training is aimed to provide a basis for continued improvement by which the overall improvement in skills and capabilities will provide a paradigm for a suitable change in organisational culture. This is within a CAS of which low carbon in UK public sector FCRM construction is deemed to be.

The UK is the only country to have legislated to reduce GHG emissions through the Climate Change Act 2008 (HM Government, 2019g), with a net zero reduction by 2050 compared to 1990 levels. UK Government set out a series of periodic carbon budgets, the fifth carbon budget set in June 2016 focused on a 50% reduction by 2030 compared to 1990 levels. The Greening Government Commitments Policy Paper set a target of 25% reduction by 2020 compared to 2009/10 levels, when it was re-published in 2016 this changed to 32% by 2020 and again in July 2018 the re-published policy paper changed to a 43% reduction by 2020. In June 2019 government legislated an amendment to the Climate Change act to net zero carbon reduction by 2050 (HM Government, 2019g). Through the Greening Government Commitments Report in 2014 (HM Government, 2014b), leading government organisations such as the EA made public commitments to meet iconic carbon reduction targets for capital (40% reduction for each project/programme) and operational carbon (45% compared to 2006/2007) by 2020, with a further commitment to net zero by 2030 and absolute zero by 2050 in October 2019 (EA, 2019d).

6.5 Action 1: Planning in order to initiate change

The construction industry needs to take a position of leadership in going beyond the position of developing innovative products and services designed with carbon reduction in mind (HM

Government, 2010). In the context of Complex Adaptive Systems (CAS), leading a change in working practices and culture, composed of elements called ‘agents’, that learn or adapt in response to interactions with other ‘agents’, the author recognised that there are no realistic ‘fully rational’ agent assumptions. The diversity that is expected as a result of the activities undertaken and the hypotheses tested, along with the continuing adaptation through an action research approach is required in order to bring about an improvement in the prioritisation of low carbon solutions. This may result in reduced cost and improved efficiency within UK public sector FCRM construction. It is under this auspice, that the researcher practitioner recognised that a leading government organisation could do better in how it quantifies, records and reports its carbon reduction. In response to the government target of net zero by 2050, the ICE infrastructure trajectory is even more important which ‘argues that whole life carbon assessment must become standard’ and that low carbon infrastructure is the way to achieve the reduction target (Morrell, 2012).

The initial research plan identified in 2014 outlined the requirement to implement a new carbon calculator: to verify its use; test the requirement; roll-out the tool and undertake a retrospective review of carbon prioritisation at options appraisal. Creating a WLCPT that aligns with the organisation’s current Project Cost Tool (PCT) (EA,2015a), became an area the author recognised needed improvement and took the steps to progress this in 2014. Following the change of approach to an action research method, the following plan was developed:

- works required to replace the existing carbon calculator with a WLCPT were:
    - carbon calculator replacement paper to NCPMS management team (EA, 2014a);
    - carbon Benefits paper (via wider support from the organisations Innovation Manager) (EA, 2014c);
    - confirmation of funding email;
    - project funding mandate (EA, 2014d);
    - project procurement strategy (EA, 2014e);
    - project scope (EA, 2014f);
    - action research approval;
- rollout and implementation of WLCPT in support of e:Mission;

- training support (face-to-face sessions delivered by the author and bought in service and WebEx sessions delivered by the author and FCRM Steering Group colleagues);
- ongoing communications.

In taking forward these activities the author secured organisational funding of £70,000 for the Carbon calculator replacement project; an element of work that the author scoped; tendered for; appointed suppliers; secured funding and project managed (EA, 2016). The delivery of the WLCPT was completed in March 2015; a summary of the timeline of actions the author has undertaken can be found in Appendix D. Due to the nature of action research the plan has continually evolved and developed. The evolution of objectives and review of approach can be found in Section 6.3

6.5.1 Whole Life Carbon Planning tool (WLCPT)

WLCPT, was launched in April 2015. This was undertaken as a 'soft' launch with the training and rollout primarily delivered to project management staff and the supply chain (EA, 2015). The launch of this work coincided with the roll out of the e:Mission 2015 – 2020 plan (EA, 2015b), offering project teams and suppliers the opportunity to be able to readily quantify the 40% carbon saving required. The WLCPT comprises two main components: Carbon Modelling Tool (CMT) and Carbon Calculator (CC). The CMT allows for a top down method to undertake whole life carbon assessments. It utilises benchmarked data from completed and approved carbon calculators. From a systems perspective, it allows for early carbon target setting, but it also ensures that design processes review carbon at an early stage ensuring that it does not become an afterthought; enabling low carbon solutions to be promoted through the capital optioneering and delivery process. The project objectives were to:

- provide a tool which assesses carbon over the whole life of the constructed asset;
- enable a link with the Project Cost Tool, (the EA's cost benchmarking tool), which would enable a relationship with cost and carbon to be assessed;
- enable project or asset optioneering based upon benchmarked historic carbon data;
- create a tool which can be utilised to set carbon targets and subsequently could lead to incentivisation of contractors as currently done with cost;
- support the promotion of low carbon solutions through early thought processes and reviewing solutions based upon carbon and not just cost.

The CMT is used to support the solution optioneering process during project appraisal stage, allowing for a comparison of up to five carbon options, as early low carbon decisions are key to maximising the overall carbon output as described in PAS 2080 (BSI, 2016). The strength of this activity within a project can set the stage for additional more bottom up approaches to be made as the project design becomes more granular. CMT can be utilised by the organisations incumbent Cost and Carbon Estimators (CCE) who also undertake the cost (PCT) estimate. Alternatively, CMT can be utilised by consultant suppliers and/or Project Managers undertaking the project appraisal; with the caveat that the same PCT asset quantification information is utilised within CMT, in order for adequate cost and carbon correlation to occur. The CMT enables a project to review whole life carbon based upon the 100-year profile, such detectors within CAS thinking, can support individual or project team thinking by supporting business requirements to promote low carbon solutions (effectors in CAS), to utilise the WLCPT (defined as an agent in CAS) to best select the least carbon intensive option. WLCPT highlights the difference between capital, operational and whole life carbon which will inform the decision-making process and allow teams to amend their approach to better reduce carbon at capital and/or operational lifecycle stage. It also has the potential to enable carbon targets to be set which could allow for supplier incentivisation.

Figure 6.2 provides an overview of the items included within each option section for the CMT; the option data is reflected within the CMT summary page which comprises of the following items:

- general project details;
- graphs with all options under the following categories per option:
    - whole life carbon;
    - capital carbon;
    - operational carbon;
    - replacement carbon;
    - refurbishment carbon;
    - demolition carbon;
    - residual carbon.
- table summary for all options covering categories above plus whole life carbon slope uncertainty.

The CMT summary page in addition to this the alignment to PAS 2080 (BSI, 2016) principles have been identified and referenced through the A to D categorisation. Further visuals can be seen in section 4.7.7 with the e-learning screen shots, Figures 4.14 to 4.17.

The WLCPT CC provides a bottom-up whole life carbon assessment, following the selection of a preferred solution at options appraisal utilising the CMT. The CC is to be utilised once the preferred option is selected, and the data must be shared with the delivery partner as part of the tender documentation. The CC should be routinely updated (monthly) in line with cost certification and formally reported at end of construction. It is envisaged that regular updates will aid design decisions. The completion of the CC requires a collaborative approach moving from the appraisal consultant to design team to contractor; each identifying carbon ‘hotspots’ throughout the stage. This facilitates a review of the method of work and materials selected. Gateway 4 end of construction carbon data is captured and utilised to create additional data points within the CMT, thereby improving the quality of data available for high-level estimation and baseline setting.

The CC reviews carbon over the whole life of the constructed asset and is based on a 100 year model; within this 100 years the tool reviews the carbon associated with the construction of the asset, the replacement of the element and any refurbishment works which might be required, alongside the operation and demolition of the element. This chain of rules allows the user to select the first intervention of the project, i.e. does it begin with a new build, a refurbishment or a demolition. It should be noted that only one data set has to be completed within the calculator to account for an intervention, as a standardised percentage is applied to allow for the carbon associated with the other interventions. The main difference between the WLCPT and the old calculator is the introduction of the CMT and the inclusion of all aspects of whole life carbon, cradle to grave assessment.

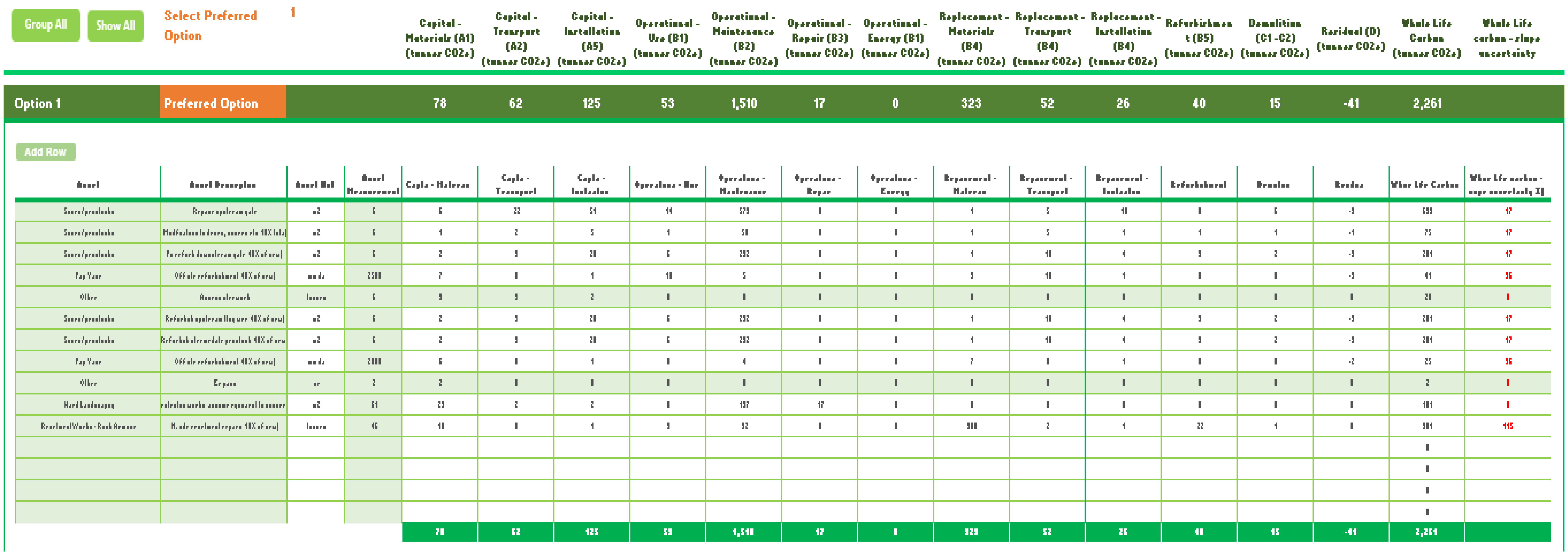


Figure 6.2 Carbon Modelling Tool options tab

The CC comprises of general project details, before being broken down into Asset and Sub asset types. Each section of the CC is linked in a logical sequence. The CC has been aligned to the RICS' 'Methodology to Calculate Embodied Carbon' (RICS, 2012), however this has been adapted to suit the needs of infrastructure projects. The data utilised within the calculator is sourced from:

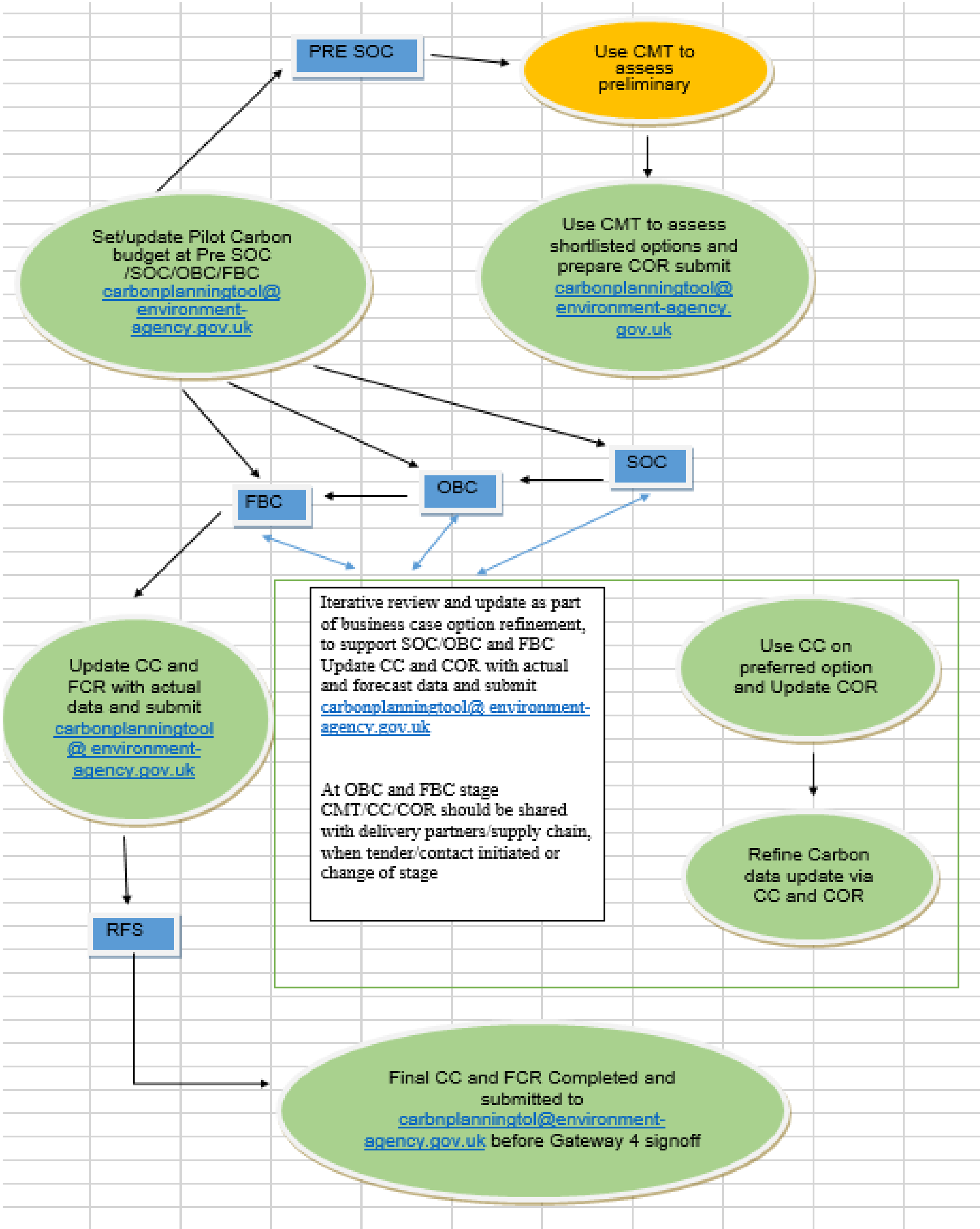
- University of Bath, Sustainable Energy Research Team. (2011). *ICE v 2 Inventory of Carbon and Energy*. Bath: University of Bath;
- Circular Ecology. (2019). *ICE v3 Inventory of Carbon and Energy*. Retrieved from www.circularecology.com: https://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.Xl4z_aj7TIU
- Institution of Civil Engineers. (2013). *CESMM4 Carbon and Price Book*. London: Thomas Telford Ltd;
- AECOM. (2017). *Spon's Civil Engineering and Highway Works Price;* oxfordshire, Spon Press
- Mineral Products. (2019). *Mineral Products*. Retrieved 9 September 2019. https://mineralproducts.org: https://mineralproducts.org;
- ICS. (2019). *Royal Institution of Chartered Surveyors*. Retrieved 9 september 2019. from https://www.rics.org: https://www.rics.org/uk/;
- HM Government. (2019c). *Government conversion factors for company reporting*. Retrieved 9 September 2019. https://www.gov.uk: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting;
- HM Government. (2019i). *The Green book appraisal and evaluation in central governent*. Retrieved 9 September 2019. https://www.gov.uk: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent;
- HM Government. (2019a). *Department for transport about statistics*. Retrieved 9 September 2019. https://www.gov.uk: https://www.gov.uk/government/organisations/department-for-transport/about/statistics;
- Department for Transport. (2019). *www.gov.uk*. Retrieved 18 July 2019. https://www.gov.uk/government/organisations/department-for-transport/about/statistics: https://www.gov.uk/government/organisations/department-for-transport/about/statistics.

The CC is divided into the following building block areas and requires the same or similar level as that of a bill of quantities, to aid the alignment to cost at a granular level, Table 4.3 WLCPT data categories alignment to PAS 2080 (BSI, 2016) provides further details.

Table 6.3 WLCPT data categories alignment to PAS 2080 (BSI, 2016)

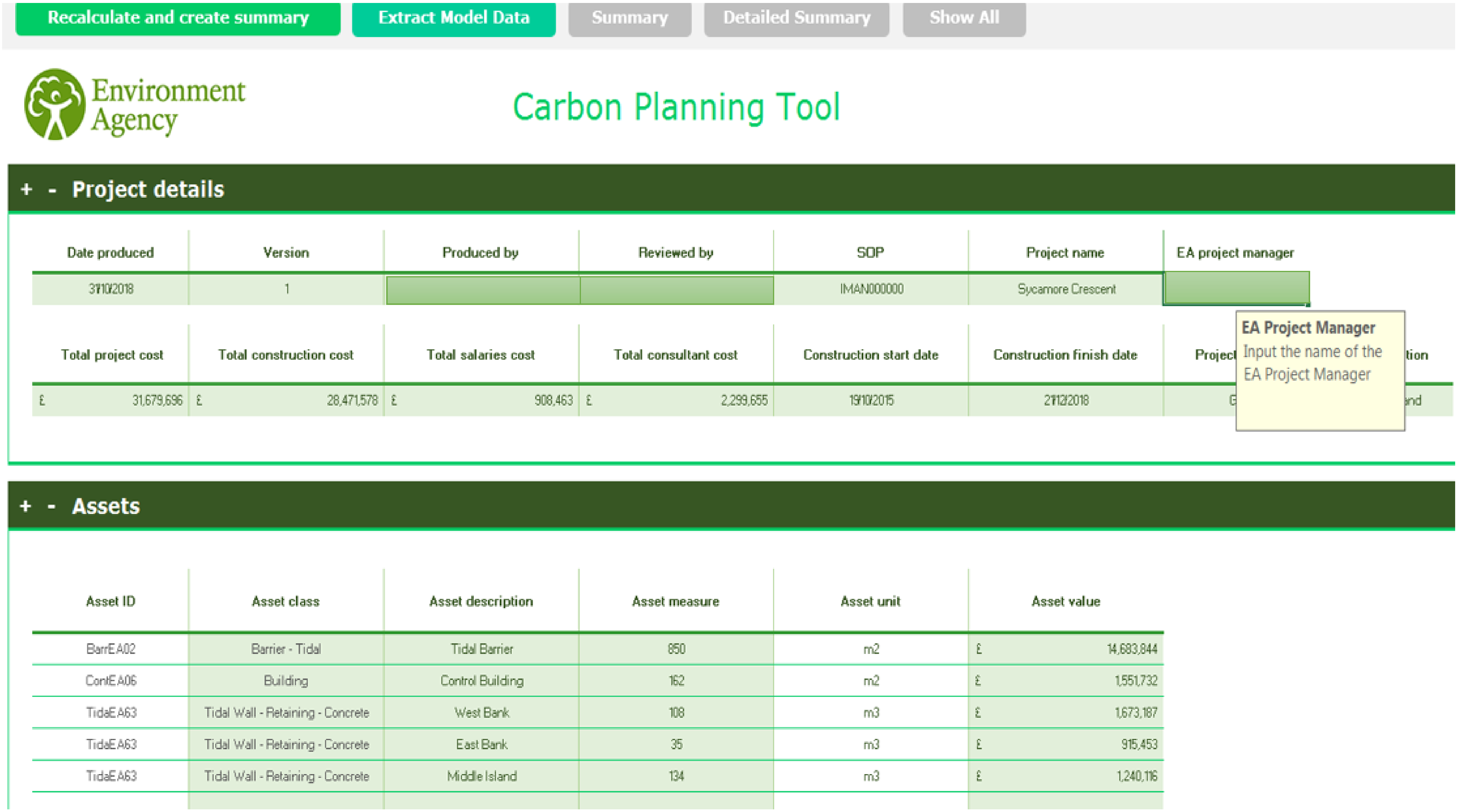
	A	B	C
1	**WLCPT data requirements**		**PAS 2080**
2	Project details		
3	Assets	Assets	N/A
4		Sub-assets	N/A
5	Capital carbon	Materials	A1
6		Waste	A5
7		Transport of materials	A2
8	Transport - Available in summary and detailed entry	Transport of Materials	A2
9		Transport of non-contractor people	A4
10		Transport of contractor people	A4
11		Transport of plant	A4
12	Installation - Available in summary and detailed entry	Site establishment	A5
13		Plant use	A5
14		Materials waste	A5
15		Other construction waste	A5
16	Operational Carbon	Use	B1
17		Maintenance	B2
18		Repair	B3
19		Energy	B1
20	Replacement carbon		B4
21	Refurbishment carbon		B5
22	Demolition carbon		C1 - C2
23	Residual carbon		D

Each section is logically linked supporting the build-up of carbon quantification by asset type, the assessment involves reviewing carbon associated with material, transport of people/plant/materials/waste and the construction process i.e. the energy required to build the element as well as the running of any site cabin. Other stages include operation of the element ensuring that any carbon associated with use/maintenance/repair/energy is captured, the demolition and the replacement of the element. Figure 4.3 outlines the WLCPT usage in-line with the 5-case business model; Figures 4.4 and 4.5 provides a sample output from the WLCPT.



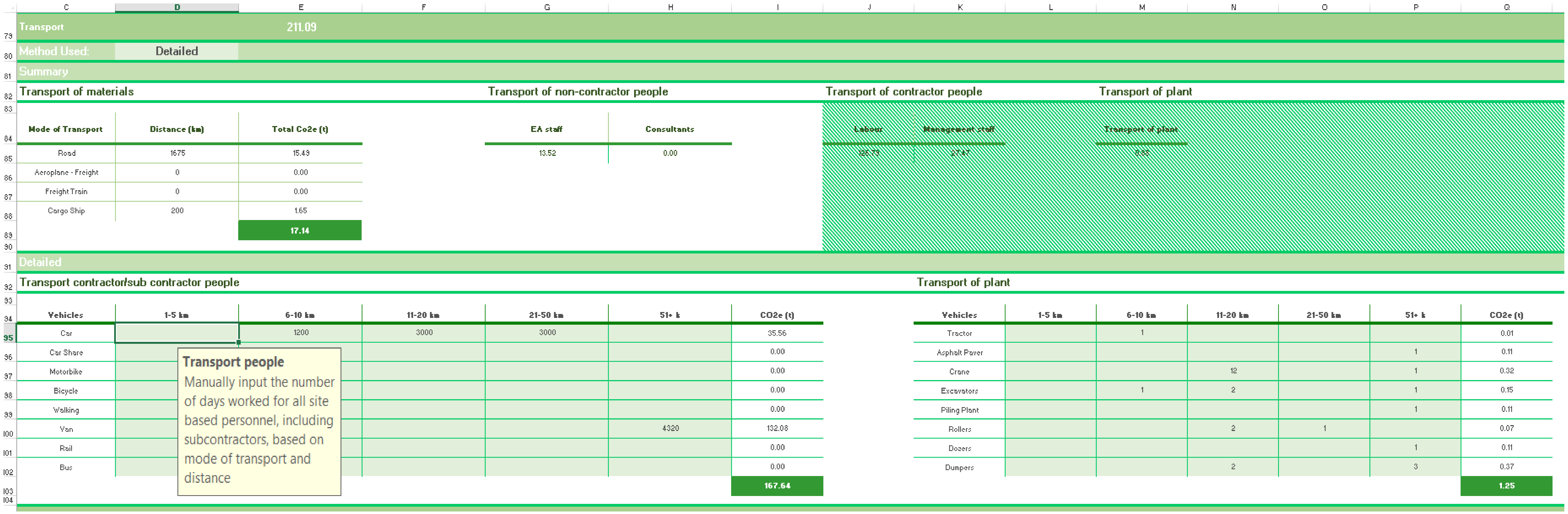
Carbon Process, green is mandatory, amber is optional, blue is project stage. CMT – Carbon Modelling Tool; CC – Carbon Calculator; COR – Carbon Optimisation Report; FCR – Final Carbon Report; SOC – Strategic Outline Case; OBC – Outline Business Case; FBC – Final Business Case and RFS – Readiness for Service

Figure 6.3 Flow Chart WLCPT Operational Instruction (EA, 2018)



Asset ID	Asset class	Asset description	Asset measure	Asset unit	Asset value
BarrEA02	Barrier - Tidal	Tidal Barrier	850	m2	£ 14,683,844
ContEA06	Building	Control Building	162	m2	£ 1,551,732
TidaEA63	Tidal Wall - Retaining - Concrete	West Bank	108	m3	£ 1,673,187
TidaEA63	Tidal Wall - Retaining - Concrete	East Bank	35	m3	£ 915,453
TidaEA63	Tidal Wall - Retaining - Concrete	Middle Island	134	m3	£ 1,240,116

Figure 6.4 Carbon Calculator Project Details and Assets



Transport 211.09

Method Used: Detailed

Summary

Transport of materials

Mode of Transport	Distance (km)	Total Co2e (t)
Road	1675	15.49
Aeroplane - Freight	0	0.00
Freight Train	0	0.00
Cargo Ship	200	1.65
		17.14

Transport of non-contractor people

EA staff	Consultants
13.52	0.00

Transport of contractor people

Labour	Management staff
126.73	27.47

Transport of plant

Transport of plant
0.88

Detailed

Transport contractor/sub contractor people

Vehicles	1-5 km	6-10 km	11-20 km	21-50 km	51+ k	CO2e (t)
Car		1200	3000	3000		35.56
Car Share						0.00
Motorbike						0.00
Bicycle						0.00
Walking						0.00
Van					4320	132.08
Rail						0.00
Bus						0.00
						167.64

Transport people
Manually input the number of days worked for all site based personnel, including subcontractors, based on mode of transport and distance

Transport of plant

Vehicles	1-5 km	6-10 km	11-20 km	21-50 km	51+ k	CO2e (t)
Tractor		1				0.01
Asphalt Paver					1	0.11
Crane			12		1	0.32
Excavators		1	2		1	0.15
Piling Plant					1	0.11
Rollers			2	1		0.07
Dozers					1	0.11
Dumpers			2		3	0.37
						1.25

Figure 6.5 Carbon Calculator Transport

6.5.2 WLCPT reporting

Carbon reporting for the WLCPT comprised of CMT and CC, Carbon Optimisation Report (COR) and Final Carbon Report (FCR). The CMT output forms the carbon baseline. This is supported by COR; the baseline is measured against the final CC to assess the overall carbon usage and whether there has been a contribution to the 40% capital carbon reduction target. The FCR provides the actions undertaken to support this data, by providing the commentary on the decisions made within the project and the contribution to carbon reduction. In 2015–2016 there was no formal reporting established with the focus being on the embedding and implementing of the WLCPT and the associated processes. The requirement to complete the COR and FCR has been a condition from the outset. However, the focus on ensuring that these were completed and received was not an immediate business priority due to the need to establish main WLCPT, associated processes and the establish consistent low carbon leadership. Further review of the reporting process is covered in section 4.7.4.

6.5.3 Carbon optimisation report (COR)

A COR provides an update on the carbon drivers for the project and the actions and opportunities available to reduce carbon and the data implemented into the WLCPT form, only one part of the wider story. The COR provides the context as to why low carbon decisions have or have not be made by the project team, picking up on the behavioural drivers, that have influenced the project carbon decisions. The report is expected on completion of the SOC and is supported by the CMT. As of March 2020, 24 CORs had been received.

6.5.4 Final carbon report (FCR)

An FCR provides an update on the actual decisions made to reduce carbon and builds upon the actions and opportunities identified within the COR. The report is expected on submission of the final CC at the end of construction, and when received provides the commentary on the decisions and reasons why carbon may have increased or decreased on the project. The WLCPT operates under a series of rules. When data is entered it generates a carbon quantification to aid project decisions; this is at both CMT and CC stages. In order to ensure that the data entered into WLCPT is supported by low carbon decision making in regards to: asset type taken forward, material type, design choices, transport and fuel; there is a requirement to provide commentary on carbon decisions. The FCR can be utilised to support the production of future case studies and analysis for wider knowledge share. As of March 2020, 11 FCRs had been received.

6.6 Action 1: Implementing the change (acting) and observing the process of implementation and consequences

The ICR (HM Treasury, 2013) recognised the opportunity to reduce carbon with the wider benefit of reducing cost and improving efficiency, PAS 2080 looks to provide guidance to infrastructure value chains to turn this into reality (BSI, 2016). The author's employer a leading government organisation, has also taken steps to align to PAS 2080 and is a signatory for ICR. Its methods and processes have matured as leadership has improved and become more visible within the area of carbon reduction; this took a clear step forward in 2015 with the launch of the e:Mission plan 2015-2020 (EA, 2015b). The organisation's e:Mission plan provides a clear way forward on where the organisation needed to improve its sustainability (and carbon) progress, these areas were as follows:

- construction carbon;
- operational carbon;
- supply chain impact;
- water usage;
- fleet emissions;
- waste;
- risk management (environment);
- total travel.

The implementation of both the WLCPT and the e:Mission 2015-2020 plan offered an opportunity to gain momentum and support to improve carbon reduction, via ways of working and systems of practice. To aid this integration a 'Lite' (EA, 2015c) version of the WLCPT was initially rolled out alongside the main version; training was undertaken to ready project teams utilising the Minor Works Framework (MWF) or Mechanical Electrical Instrumentation Control Automation (MEICA) frameworks to record and report on carbon.

Leaders within the organisation had made clear commitments to carbon reduction and climate change mitigation and adaptation (RSA, 2018). However within the first 12 months of the e:Mission 2015-2020 plan and the WLCPT being implemented, there was clearly an imbalance in the prioritisation of low carbon, with it not being a key project driver for successful delivery. Reporting on carbon returns did not occur until 2017 along with the Key Performance Indicator being set for Area Directors (EA, 2017). The realisation that a change from a 10% to a 40% capital carbon target and the challenges this would create was not recognised by project teams, who viewed carbon reduction simply as 'another thing to report', and not a fundamental part of the decision-making process. Figure 4.6 provides an example of the cascade slides provided for internal staff.

Having observed this outcome and with the added benefit of being removed from the process for five months, there was a clear need to change the carbon focus from optional to mandatory, supported by more frequent communications of requirements, additional WebEx and face-to-face training sessions. In addition to this, the external promotion of the WLCPT continued, with the author taking a lead in promoting the works to implement the WLCPT by entering awards, undertaking public communications and ensuring that the availability of the WLCPT was accessible via the .gov website (EA, 2016b). Further information can be found in Appendices I and K.

Figure 6.6 Cascade slide (EA, 2016d)

6.7 Action 1: Reflecting on processes of change and re-planning

Reflecting on the processes of change and re-planning, it was evident that carbon reduction was not embedded within project decision-making processes and the implementation of a WLCPT and supportive training was insufficient for: OB4: To investigate whether quality of training influences low carbon prioritisation ; OB6: To investigate whether tonne of carbon influences cost; OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influences cost and OB8: To investigate whether type of training influences tonne of carbon. Reporting returns were extremely low with only the old version of the carbon calculator being submitted. It is through the implementation of the WLCPT that the author through reflection, local and national discussion concluded that the following challenges had emerged and needed to be addressed:

- a gap in prioritisation of low carbon through inconsistent leadership messages;
- lack of clarity on when and where the WLCPT should be used;
- perception that low carbon options were too costly and therefore the promotion of low carbon is an inefficient use of resources;
- perception that the WLCPT was too difficult to use and asked for unnecessary information;
- questioning the suitability and appropriateness of the WLCPT;
- overall lack of awareness of the new WLCPT.

With the onset of the organisation's potential failure in achieving its 40% capital carbon target; the author, along with learned colleagues within the FCRM Steering Group painted a clear picture to the FCRM Business Board and PCM management team that greater priority of carbon reduction needed to occur.

Recommendations from the March 2016 FCRM IEM 2020 Plan Update and Infrastructure Carbon Review Reporting paper (EA, 2016c), were to:

- note the progress and continue to provide support and leadership for the FCRM IEM 2020 Plan;
- note and support the approach set out in the ICR report;

- agree to address sustainability for each paper brought before the FCRM Business Board and agree to amending the FCRM Business Board template to include a statement regarding sustainability;
- support the process for managing and reporting on whole life carbon including consideration in all new procurement strategies, frameworks and contracts.

Recommendations from the Carbon Planning Tool 2016 Opportunities and Actions (EA, 2016e), were to:

- note the progress and continue to provide support and leadership to the WLCPT;
- agree to resourcing the current WLCPT implementation and the future support of the WLCPT ‘Lite’ for MWF, MEICA and in-house construction works, until which time organisations systems allow for some automation and self-supporting of WLCPT (via BIM and CAMC3);
- support the process for managing and reporting on whole life carbon including consideration in all new procurement strategies, frameworks and contracts;
- support the Carbon Assurance activities focusing on continued improvement through sharing of key lessons and best practice from the COR and FCR across the business, with updates to the Carbon Models undertaken in a minimum of twelve months’ time.

The move from implementing, supporting and promoting the WLCPT as a project undertaken alongside the author’s role as a Commercial Services Manager, became a fully embedded author activity with the opportunity to fully immerse into the role and provide leadership at the author’s level within the organisation. A series of actions were undertaken from April 2016 to March 2017; a summary of the timeline can be found in Appendix D. The following actions were undertaken directly by the author; specific bought in services managed by the author and a wider network of supporters via the FCRM IEM Steering Group, re-planning the approach and activities to be taken forward for April 2016 to March 2019. Reflection on the level of organisational cultural influence. Through the implementation of a WLCPT can only be truly tested through the evidence of the low carbon solutions being implemented on projects resulting in reduced cost and improved efficiency and whether this is a repeatable and consistent process. In order to enable this analysis to be undertaken, through an action research approach and the continued reflection, re-planning and action on continued improvement changes the following areas have been focused upon. To establish an improved basis in organisational skills and capabilities regarding carbon reduction:

- continued improvement of the WLCPT;
- communications;
- training;
- reporting;
- promotion of the WLCPT (this will be expanded in section 4.9).

The following sections will expand on these areas further.

6.7.1 Action 1: Communications

The low level of uptake for the WLCPT in the first year of implementation, reflected that there was a lack of awareness in regards to its existence and application, moving the thinking from ‘another thing to report’ to a ‘key activity at aid low carbon decisions’ was needed. Through a series of communications aimed to provide specific team updates, general awareness raising and the focus on specific elements of the WLCPT; a ‘hearts and minds’ approach was taken, viewing low carbon as something familiar, accessible and done by all. A simple starting point was the creation of a central email to ensure that communications regarding the WLCPT and carbon reduction could be sent to one location that could be overseen by more than one person and to depersonalise the WLCPT from the author and to embed it further into business as usual.

Several opportunities for wider organisation and supplier involvement have been undertaken through the encouragement of carbon champions to be put forward by each project unit, so they are more involved, have a direct link into the latest updates and knowledge share items, and to promote carbon reduction at a local level. This to a certain extent was a challenge, with only one willing volunteer coming forward in 2016, requiring the need to reassess the approach for staff and supplier involvement in the wider carbon integration process. Requesting the involvement of carbon champions in regular carbon catch up calls undertaken, every six weeks, this was compounded by the perceived ‘success’ of the WLCPT and the acceptance of a change in the way of working within the organisation and supply chain. Although the attendee list had 33 invited, it was regularly 8-10 of the same willing and motivated individuals who dial in to gather the latest information to share back with supplier organisations or local teams. Building up a network outside of the organisation and the main FCRM Steering Group network was essential to getting buy in and much needed visibility of the work being undertaken. Further details on the timeline can be found in Appendix D, along with evidence of communications undertaken in Appendix E.

The author learning from organisations such as BBC and Marks and Spencer who have named their carbon tools, recognised that part of the process of embedding the WLCPT was to ensure that individuals could easily recognise it and refer to it, in a friendly and familiar way. Calling it a whole life carbon planning tool (WLCPT), did not encourage individuals to drop it into a conversation. Therefore, the WLCPT was turned into a branded product that individuals could easily remember the brand name. The author carried out a competition via the internal cascade in December 2016 to name the WLCPT. Figure 4.7 is the slide provided to national cascade to name the WLCPT.

Following the competition 'Eric' was created along with a logo. To support this route forward £5,000 of marketing funding was secured by the author to purchase 99.9% recycled coasters and mouse-mats. The creation of the Eric identity and the availability of merchandise shared with organisational staff and suppliers, allowed for a prominent visual image of carbon reduction and Eric to be ever present around individual's day-to-day environment. Through the utilisation of a logo, email banner and associated marketing material, talking about carbon became a more comfortable task as project team referred to Eric more readily as part of their daily conversations. It also provided a visual to be utilised within presentations, workshops and conferences. The remainder of this thesis will continue to refer to Eric as WLCPT for continuity. Figure 6.8 and 6.9 are the visual imagery used for promoting WLCPT.

Figure 6.7 National Team Cascade December 2016

Figure 6.8 Eric Logo

Figure 6.9 Eric email banner

Organisational and supplier communications within the second year of implementation (2016), were focused on ensuring that awareness of WLCPT existence and appropriate application were suitably applied. Reinforcing the link to corporate plan and where and how WLCPT can be accessed via internal Easinet and external Asite organisational systems. In addition to key messages on how WLCPT provides a step by step guide on the front page to get users started, this is supported by comment boxes providing prompts, to support the Operational Instruction on how to complete WLCPT. Other key communications focused on specific elements of WLCPT such as COR and FCR reporting requirements, what they covered and how the information would be utilised. This was reinforcing the message that it is not reporting for reporting's sake but to ensure that trends and best practice and lessons learnt could be more widely shared. Figure 4.10 provides the cascade slide promoting the need for COR and FCR reporting. Further information on communication examples can be found in Appendix E.

In addition to these regular communications the author, continued to develop her own skills and capabilities attending seminars and workshops. The Salford University low carbon seminar resulted in a contact being made with Natural Resources Wales. This was followed up and face-to-face training on WLCPT was implemented in January 2017. The ICR seminar also reinforced requirements to enable better comparison between cost and carbon. In raising awareness of the availability and use of WLCPT, the author presented at the organisation's supplier chain conference (in June 2016) along with presentations to internal teams ranging from commercial teams, operations managers, National Environmental Assessment Service (NEAS), and to external suppliers and wider industry representatives at the Flood and Coastal conferences in 2015 through to 2019.

The availability of a 'Forum for the Future' graduate in the summer of 2016 provided a valuable resource to focus specifically on the production of a communications and stakeholder engagements plan (EA, 2016f). This was taken forward as part of embedding and sustaining the continued utilisation of WLCPT. This provided a valuable steer as to the stakeholders that needed to be engaged to embed the utilisation of WLCPT further.

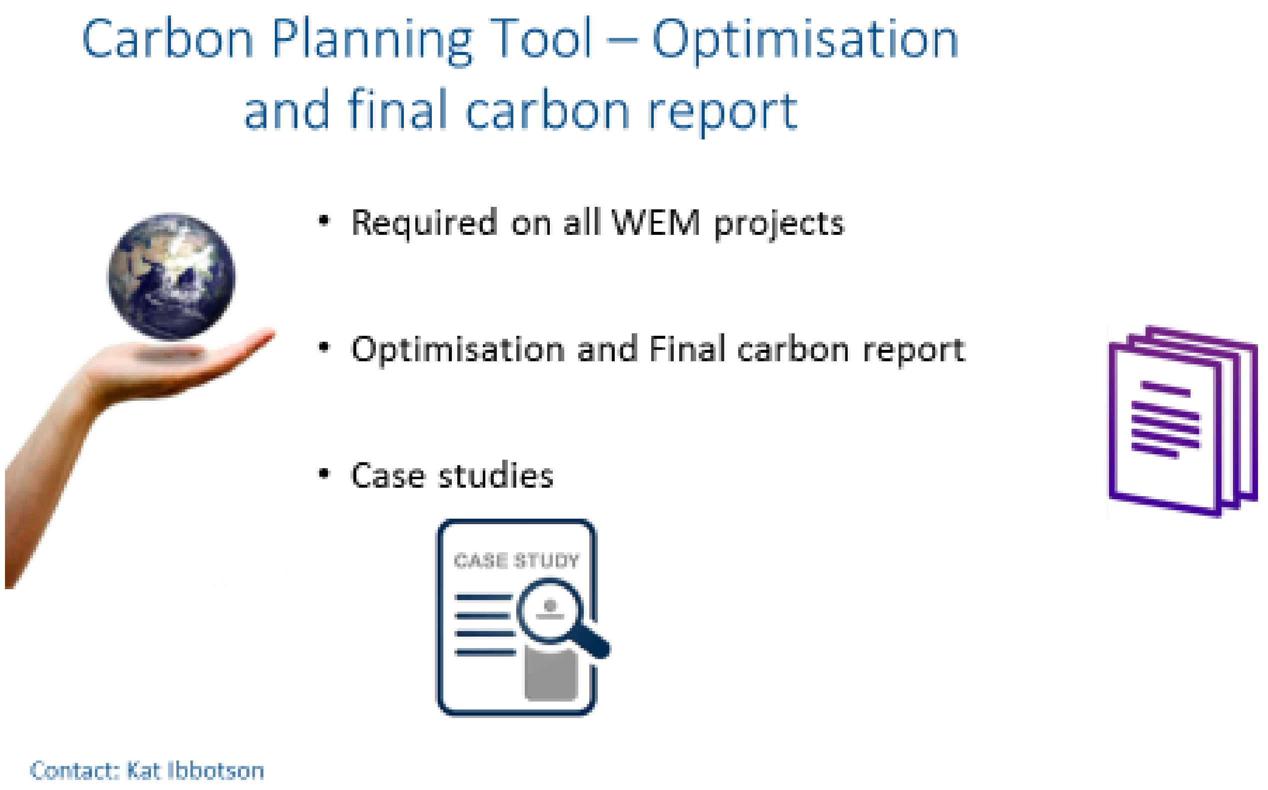


Figure 6.10 June 2016 Cascade Slide

Communications have been both a friend and a foe, during this research study. It has been a valuable way of updating and informing the organisation, supply chain and the public, of WLCPT availability and the continual improvement changes that it has had through its development. However, it has also been a significant element of the Carbon Planning Manager role (EA, 2017a), to provide the necessary awareness raising messages, tailored to different audiences. One of the successful items has been through the implementation of the 'Low Carbon Future' DEFRA Yammer group, initially started as an EA Yammer group in 2017; the update of the system to DEFRA offered the opportunity to also update the group page. It is now available to internal staff, supplier and other public users of WLCPT, and provides a central knowledge share site, with links to available case studies, factsheets (EA 2018d) and low carbon information. As of March 2020, the group had 451 members. Further information on communications and reports can be found in Appendix E. Figure 4.11 provides a screen shot of the main Low Carbon Future Yammer page. Yammer is a social networking service used for private communication within organisations.

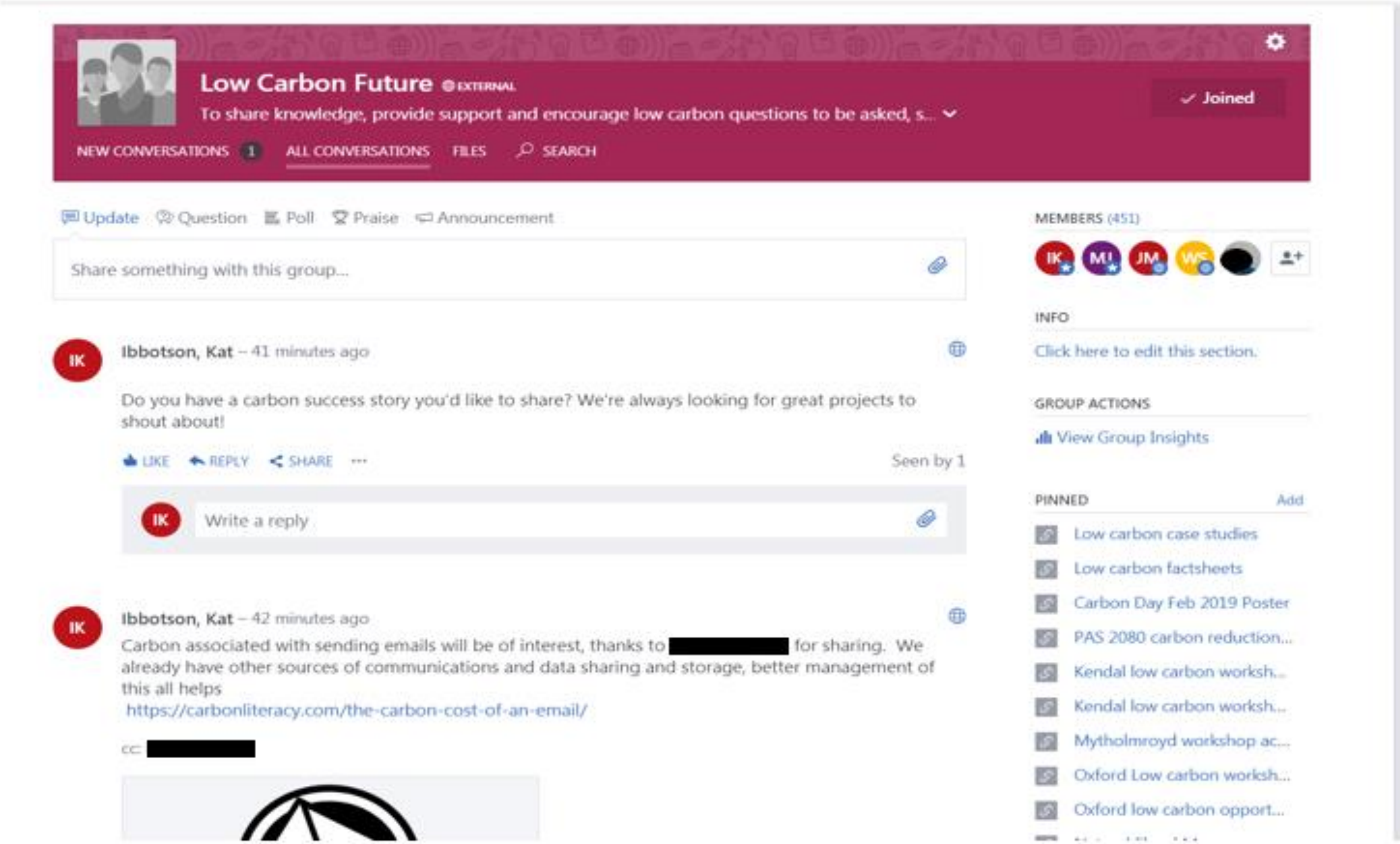


Figure 6.11 Defra Yammer Group

6.7.2 Action 1: Continued improvement of WLCPT

As part of the scope and future development of WLCPT, the author had already identified the need to continually develop and improve its capabilities at the outset. Having built in the ability through the 'Other' function to create additional assets and sub-assets when they were not available as part of the standard drop down lists via the CMT and CC. This was with the overall intention of adding in new asset categories as CC were completed and uploaded to the CMT to create new data points. However, as part of the early feedback, additional plant types were added to the central list upon the request of project teams. Through feedback questioning WLCPT's suitability alongside the improved training and awareness raising of WLCPT. The author had identified this barrier to embedding, as being a direct result of individuals not following the current guidance, with a list of common user errors that would cause the Excel sheet to stall or run errors, or be rejected as completed CC were:

- manual over typing of drop-down lists resulting in carbon not being quantified;
- missing project details;
- missing costs from asset types;
- CC returned in summary form rather than detailed form;
- waste not identified;
- operational carbon left blank.

In addition to the main WLCPT the implementation of the 'Lite' version stalled due to the timescales in implementing updates to new MWF and MEICA frameworks. In addition to this, those that did attempt to utilise both versions of the WLCPT found that the main version offered better opportunities for recording savings made at site set up and transport, an element which is set permanently in summary mode with the 'Lite' tool. It is due to this, that the 'Lite' tool was left unsupported and removed from use in 2017, in favour of supporting the wider implementation of the main WLCPT.

Additional observation and review from teams via cascade briefs and emails to the carbon planning tool email address, highlighted the need for an independent review. With feedback via the central email address also raised the specific issue of trust and confidence, and whether the client organisation had implemented something that was fit for purpose. An independent review was commissioned and undertaken by a consultant from organisations supply chain, the findings were completed in January 2018 (EA, 2018).

The WLCPT (Eric) review identified the following key items: WLCPT is ‘industry leading’, being ‘most comprehensive’ in the carbon the tool captures and ‘innovative in its approach’ as to how completed calculators are used to create new data points within the carbon modelling tool. The independent review looked to address the following points:

- assess whether the tool meets the original objectives;
- provide assurance of the validity of all processes and tools within WLCPT used in calculating carbon for individual projects;
- are the calculations appropriate and the available selections clear, particularly for types of plant available;
- is the amount of information asked for, appropriate to calculate the required data for accurate carbon data capture and reporting;
- improvements, to ensure user experience is clear and straightforward and the outputs generated are suitable for our requirements.

The findings identified the following improvement actions to be taken forward:

- including uncertainty within the CMT;
- addressing calculation issues – double counting, error in applying residual emissions, and error when applying one asset of the same type;
- providing better guidance on what is expected for refurbishment/replace as first intervention;
- splitting the Operational Instruction (OI) to provide better documentation on the tool mechanics (methodology);
- address issues around visibility and policing of the process and identify key people to do this;
- update approach to discounting;
- present residual emissions as a separate part of the calculation and do not subtract from totals;
- resolve minor calculation errors identified;

- provide further training and guidance (including visuals);
- formally document review process;
- develop a process for updating emission factors and impacts on CMT/baselines;
- present reporting in line with PAS 2080 (BSI, 2016) naming conventions;
- include function within the CC to accepts data from other sources (i.e. bespoke emission factors);
- include further emission factor data items such as pumps, fencing and cables.

All but one of the actions identified were taken forward and a comprehensive update to WLCPT, CMT, CC and OI was undertaken and implemented in May 2018. The availability of additional data models was not taken forward. The principle around this was based on the completion of the CCs being the source for creating new data points. Any new models added would have to be theoretical ones, which were time consuming to create due to the lack of historical data available for the data model asset types in question. It was also deemed that since there was already the function to include additional asset types under 'Other' within the CMT and CC then this would not be an effective use of resources.

The following activities were taken forward by the organisations' Cost and Carbon team with the author taking a key role in supporting and managing projects on behalf of the organisation by:

- project managing work to update WLCPT and supporting OI - undertaken by organisations' supply chain consultant;
- supporting project to review low carbon best practice – undertaken by organisations' supply chain consultant;
- project managing e-learning module – undertaken by training provider;
- project managing implementation of low carbon best practice workshops – prepared by organisations' supply chain consultant and facilitated by a leading independent expert partner in carbon reduction.

The Low Carbon Best Practice report (EA, 2018) utilised historical project data (also utilised for the WLCPT tool data models) and provided a comprehensive report (EA 2018b), case studies and factsheets (EA 2018d) referring to low carbon solutions that are available for teams to be taken forward; these factsheets and case studies formed the content of a low carbon workshop. Further details on this training can be found in section 4.7.3 and Appendix G.

As part of the continued improvement activities, the author secured £5000 of funding from the organisation to part fund the update of the Inventory Carbon (embodied) database (ICe), following a request from Circular Ecology. The progression of this work has resulted in a small steering group being formed from the Rail Safety and Standards Board, Heathrow Airport and EA to ensure that the update meets the expectations of each funding organisation. This update was rolled out in May 2019, supported by presentations from the funding organisations, which the author undertook on 31st May 2019 at RICS.

6.7.3 Action 1: Low carbon future programme

Information externally assessed and verified as part of the Eric Assurance and Low Carbon Best Practice Report has led to a series of work streams being progressed as part of a Low Carbon Future (LCF) programme, commissioned by the organisation and project managed by the author. The LCF programme included the following activities:

- Minimum Technical Requirements (MTR) review;
- cost, carbon and efficiency correlation;
- carbon budget;
- Natural Flood Management (NFM) case studies (EA, 2019h, EA, 2019k).

Further information can be found in Appendix G and J.

6.7.4 Action 1: Cost, carbon and efficiency correlation

One of the main objectives from the creation of WLCPT was to be able to better align cost and carbon. The intention has been to utilise this data at project and programme level to provide an improved cost and carbon approach to decision making. At project level, WLCPT CMT and PCT outputs have been utilised to aid decision making. However, full information is often inconsistent with only one option checked for both cost and carbon, rather than for multiple options. One of the barriers to this is the need to manually enter information into two separate spreadsheets. To improve practices, updates to the 5-case business model template (HM Government, 2019h) have been put forward by the author (updates were submitted March

2019, and have been included as part of a wider review of the template); to ensure that information provided to demonstrate that both cost and carbon has been reviewed for all shortlisted options, within the business cases submitted for approval. Collating this level of information at a programme level has been attempted several times, with automated spreadsheets created to gather in CMT returns, however these have had limited success with the continued update of WLCPT proving a barrier, requiring additional updates to the collation activities. As an alternative the final capital cost and capital carbon calculator and efficiency reporting information has been collated to provide a cost, carbon and efficiency correlation. This has been utilised to de-myth some of the ‘low carbon is too expensive’ challenges, and supports the low carbon case study and factsheets which provide evidence of the cost and carbon savings achieved on historic and current live projects, as illustrated in Appendix G, Variable Date; all of which provide substantial and clear evidence in support of OB6: To investigate whether tonne of carbon influences cost.

Of the carbon information reported up to quarter 4 2019/2020, where a PCT cost was received, the four box model outlines that the majority of projects fall into the low carbon low cost category. Where efficiency information has been available and included within the analysis, again the majority are contained within the low carbon low cost category apart from two low cost high carbon category, which has resulted in a low cost, high carbon category due to the purchasing of material from overseas rather than locally sourced, this decision was driven by cost savings rather than the consequences of carbon usage. Figure 4.12 provides a visual diagram of the information available, the amber points identify cost and carbon data, green points identify cost, carbon and efficiency data, the size of the efficiency saving is demonstrated by the size of the point (the larger the circle the greater the efficiency), further details can be found in Appendix J.

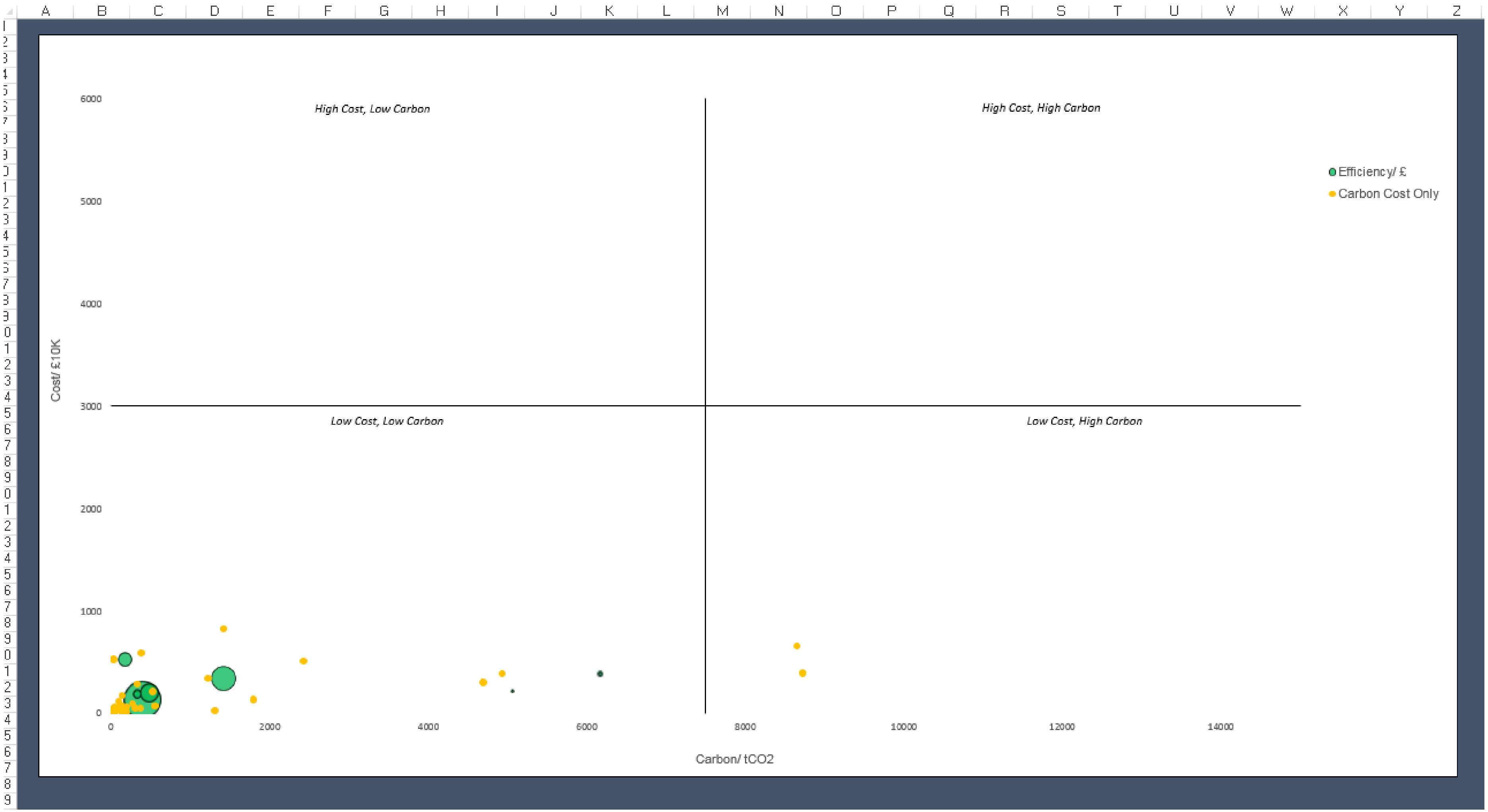


Figure 6.12 Carbon, Cost and Efficiency 4 box model, Q4 update March 2020

6.7.5 Action 1: Carbon budget

Feedback from the WLCPT (Eric) Assurance Report (EA, 2018) and the challenge in collating baseline information raised the opportunity to further review how the organisation sets its carbon baseline. At present this is carried out by selecting the most likely preferred option to be taken forward as part of the CMT review of options. This presents the following challenges:

- savings identified and implemented before the CMT is undertaken are not incorporated into the capital carbon reported savings;
- the CMT process forces the most likely option to be selected as a baseline. Through project changes, the final scheme built is often significantly different from the initial option selected, making the comparison between CMT baseline and CC actual challenging;
- the CMT process is high-level for optioneering purposes and is built upon data from major projects. Although it has the function of ‘other’ for alternative assets, it is primarily FCRM focused and does not encourage other project types to utilise WLCPT. In addition to this it over estimates minor works or refurbishment schemes.

The author commissioned and project managed the LCF programme, the carbon budget work, consisted of a review of all of the submitted carbon data from 2015 to 2017, along with information held within the organisations Area Programme team was utilised to assessed alternative metrics. In order to set a ‘Carbon Budget’ for Area Directors to ‘own’ based on their delivery programme along with providing an early and clearer metric for project teams and programme managers to measure progress against. The metrics included within the review were as follows (EA, 2019c):

- carbon per outcome measure 2 (OM2 – houses protected that move risk areas);
- carbon per asset type;
- carbon per present value cost;
- carbon per present value benefit;
- carbon per total number of properties protected.

Each of the metrics identified present challenges, due to the available data source; returns are primarily via WLCPT. However, the old version of the calculator which provides only capital carbon information has also been included within the data source. The following metrics were removed from review (EA, 2019c):

- carbon per OM2 – many of the OM2 figures provided were 0, as this measure only accounts for houses that have been moved across categories, thus, providing insufficient data for analysis;
- carbon per asset type – this metric is to be monitored over time as data from CC returns is gathered in order to review in the future. At present WLCPT splits asset type out by whole life carbon, whereas the metric used for carbon reporting across the organisation is capital carbon only. This therefore would not be comparing CO_2 on a consistent basis;
- carbon per present value benefit - this metric has been removed from the analysis process due to the variability and subjectivity of the present value benefit data, resulting in its proposed benefit as a metric being too volatile.

The remaining two metrics carbon per Present Value Cost (PVC) and carbon per Total Properties Protected (TPP) were taken forward for further review. With gaps in the existing data at the time of the LCF carbon budget assessment the mean result is 2.6 tonnes carbon per £10k Present Value Cost. Table 6.4 provides further information on PVC averages for six projects where data has been available in 2018 and 2019.

Table 6.4 Carbon per Present Value Cost averages (EA, 2019c)

Year	Project	Present Value Cost data (£10k)	PVC Carbon budget (CO2 tonnes)	Current CMT baseline (CO2 tonnes)	CMT baseline above or below current budget
2018	A	560	1473	1421	4
2018	B	508	1338	727	46
2018	C	52	137	70	49
2018	D	28	73	83	- 14
2019	E	218	574	1232	- 115
2019	F	703	1848	1034	44

This data was tested on the list of projects which currently have both carbon and PVC data. The results show a mean of 2% above budget for carbon estimated using the method, indicating the budget is set too low (EA, 2019c).

The carbon per TPP provided a wider data set for analysis, it was still not a complete data set; the average across the three years as reported provide a result of 5.6 tonnes carbon per household protected. In assessing the suitability of the averages provided, the 2018 and 2019 data available was reviewed, resulting in the average data being adjusted further:

- t CO_2 per Present Value Cost – 2.58 (98% of the average calculated);
- t CO_2 per Total Properties Protected – 3.14 (56% of the average calculated).

The piloting of the alternative carbon budget approach, alongside the current CMT baselining has been agreed by the organisation and has been included within the COR and FCR reporting. A more challenging t CO_2 per Present Value Cost (PVc) – 2.58 figure has been reviewed further. With a gradual reduction in t CO_2 per PVc increase has been analysed. Table 6.5 provides the PVc range and weighting included within the pilot budget reporting. The assessment of the PVc range against the actual returns can be seen in Figure 4.14. the initial weighting of 2.37 tonne of carbon, became excessive at the tipping point of £30,000,000 offering no effective challenge to reduce capital carbon. The resulting ranges were assessed based upon a review of the historic final carbon returns against the available PVc data. Further analysis of this is required in order to be deemed a robust data set.

Table 6.5 Tonne carbon per PVc range

	A	B
1	Present Value Cost (£) range	Carbon average (t) weighting
2	0 to 30,000,000	2.37
3	40,000,000 to 70,000,000	2.01
4	80,000,000 and above	1.71

Building upon this data the challenge of providing the CO_2 per £ cost is continually raised by the organisation in regards to being able to quantify the value. This ongoing challenge has been hampered by the availability of data for both cost and carbon. In August 2019, this issue was again raised, and through the LCF programme a revised metric was included within the budgeting approach: Capital Carbon (t) per Capital Cost (£) and Whole life Carbon (t) per Capital Cost (£). Utilising this approach also allowed for a review of the amount of sequestration (t) required to achieve the new net zero request and how this relates to sequestration activities i.e. trees planted.

Table 6.6 provides the proposed outputs of the high-level review. Budgets set compared against reported CMT and CC values can be found in Figure 14.4. As a result of this work the trial of three pilot carbon budgets: t CO_2 per PVc; t CO_2 per Capital cost and t whole life CO_2 per Capital cost. These are to be utilised to: improve the data available for analysis; establish appropriateness of the measure and the accuracy of the budget allocation. Data within Figure 6.14 shows how PVc budget currently does not provide a sufficient budget profile, further review of the PVc range has demonstrated that the data available is currently insufficient in size with significant variations within each range, although the budget will remain as its current level for the pilot stage, additional PVc data is required for a greater number of projects before it will be reviewed further. T Capital CO_2 per cost highlights an adequate allowance with CMT Gateway 1 baseline and Gateway 4 actual carbon, remaining within the allocation; whole life carbon provides more of a challenging profile with a gradual reduction from Gateway 1 to Gateway 4 but still remaining within the budget allocation. The assessment of the capital and whole life carbon per cost against the actual returns can be seen in Figure 6.14.

Table 6.6 t CO_2 per cost

	A	B
1	t CO2	Cost £
2	Capital carbon 5.28t	10,000
3	Whole life carbon (100-year cycle) 8.2t	10,000

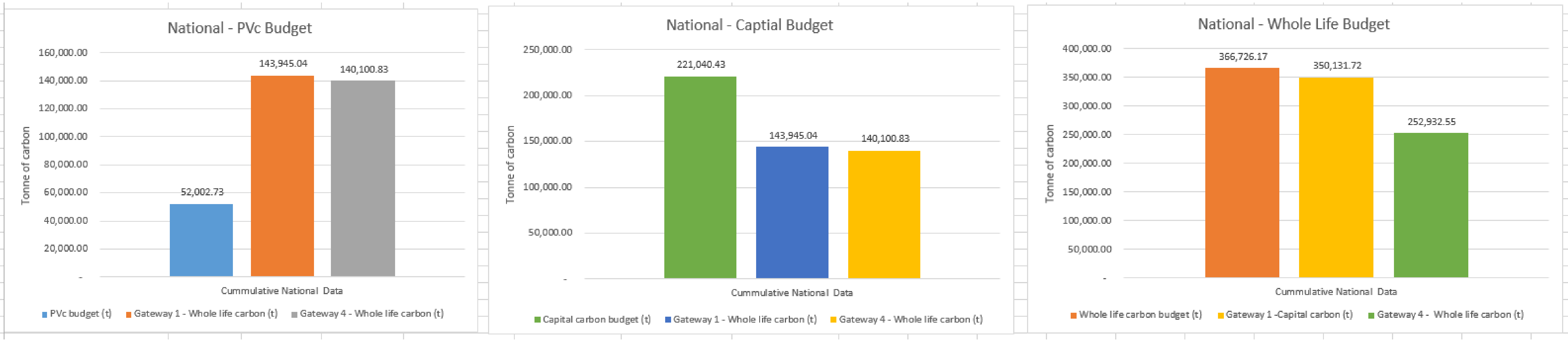


Figure 6.14 Graph of National reported pilot budgets.

6.7.6 Action 1: Natural flood management (NFM) case studies

The author commissioned and project managed the LCF programme NFM case studies which were created in conjunction with the Forestry Commission. NFM is also known as Working with Natural Processes (WWNP) (EA, 2017c) and aims to retain, reinstate and emulate the natural functions of river catchments, floodplains and coastal processes to reduce flood risk. Despite an increasing number of studies investigating the benefits that NFM can provide in reducing flood risk, little work has previously attempted to quantify the potential carbon savings that may be associated with the implementation of such measures. The LCF NFM case-studies focused on developing a methodology for quantifying and measuring the carbon impact (emissions and sequestration) associated with the 14 NFM measures outlined in the WWNP directory (EA, 2017), and how these are quantified within WLCPT.

The aspects of NFM schemes identified in the LCF NFM commission identified the following items as being important when assessing carbon impact:

- materials and plant machinery used in the construction of NFM measures;
- sequestration from planted vegetation or land use change;
- avoided construction of traditional ‘hard’ flood defence assets which typically use carbon intensive materials such as concrete in greater quantities.

Further research found that quantifying the specific flood risk benefits of individual NFM schemes lacks precision. This makes it challenging to link NFM measures to the avoidance of individual ‘hard’ flood defence assets. Subsequently, this project focused on carbon sequestration and construction emissions from NFM schemes (EA, 2019f).

Given the variety of NFM measures, it is not possible to calculate the carbon impact of all schemes using a single methodology. Therefore, three categories of NFM measures were created with an approach to calculate the carbon impact developed for each NFM measure involving (EA, 2019f):

- woodland creation;
- land-use change (not woodland creation);
- construction/landscaping.

Further examples of NFM carbon sequestration case studies can be found in Appendix G. The inclusion of carbon sequestration opportunities formed part of a wider update to WLCPT, further details can be found in Appendix F.

6.7.7 Action 1: Training

It is through ongoing communications by the author that the availability of training has been promoted. Type of training content has developed significantly since the availability of WLCPT; initially being provided by the author, supplier bought in service, via a wider network of carbon champions from the FCRM Steering Group and Sustainable Business team (formerly IEM), and webinars which provided an overview of the organisation's drivers, awareness of WLCPT and when it should be used. Specific face-to-face sessions had been undertaken by the author for both the main and 'Lite' versions of the tool. In undertaking these training sessions and requesting feedback from WLCPT users; the benefit of being taken through in detail how to complete WLCPT was raised as being a key requirement. This was subsequently supported by the findings from the WLCPT (Eric) Assurance report (EA, 2018) which highlighted the need for more comprehensive training. Sustaining the current face-to-face and webinar approach however was not practicable and in February 2018 works were progressed to put together two training modules around low carbon, funded by the organisations Sustainable Business team:

- low carbon awareness e-learning module;
- WLCPT (Eric) e-learning module.

The WLCPT (Eric) e-learning module became a key product of the author's work to ensure that the quality and usability of the tool was readily transcribed into an online learning activity. Challenges arose regarding the understanding of the context and subject area by the service provider requiring greater input from the author and Sustainable Business colleagues along with improvement to the visualisations. This resulted in a delay to the delivery of the WLCPT (Eric) e-learning module which was rolled out to the organisation and supply chain in September 2018. The WLCPT (Eric) e-learning module is available via the internal Learning Zone portal and is a mandatory requirement for internal staff involved in the delivery of asset management; this data is utilised for the testing of OB8: To investigate whether type of training influences tonne of carbon. An external link is provided to framework suppliers and to external users of WLCPT as part of the delivery of WLCPT and supporting documents:

https://ericenvironmentagency.co.uk/

Figures 6.14 through to 6.17 provide screen shots from the WLCPT (Eric) e-learning module; note graphical representations refer to tone of carbon on the vertical axis and options reviewed on the horizontal axis. As of December 2019, the WLCPT (Eric) e-learning module had been completed by 204 delivery staff (NCPMS/PCM/NEAS/other delivery) and 83 FCRM staff with an additional 144 individuals having identified the requirement within their training plan. This improvement in training has had a direct link to the reduced level of errors being produced through the completion of the CC. Being Excel based with a large number of embedded macros, it is prone to errors when areas are over written, causing the tool to stall. As outlined in Section 6.7.2.

In addition to the practicalities of completing WLCPT, the output from the Low Carbon Best Practice review (EA, 2018) was supported by the author through the implementation of a series of 16 workshops facilitated by an independent expert partner in carbon reduction. The workshop was aimed at client and supplier project team members. The content set out the benefits for promoting low carbon solutions in construction whilst also providing evidence on where this has already been undertaken with UK public sector FCRM construction projects implemented by the author's organisation. This provided evidence to break the myth that low carbon is too costly to implement. The workshops focused on attendees looking at how examples provided can also be implemented on current projects; further information on the slides and available case studies can be found in Appendix G. As of October 2018, 16 workshops were undertaken with 178 attendees from the client organisation and 35 framework suppliers attending. The author has also utilised this workshop agenda to undertake a training workshop with the MSc students at University of Bolton and has incorporated the training requirement within the organisation's graduate training scheme.

Figure 6.14 WLCPT (Eric) e-learning screen shot 1

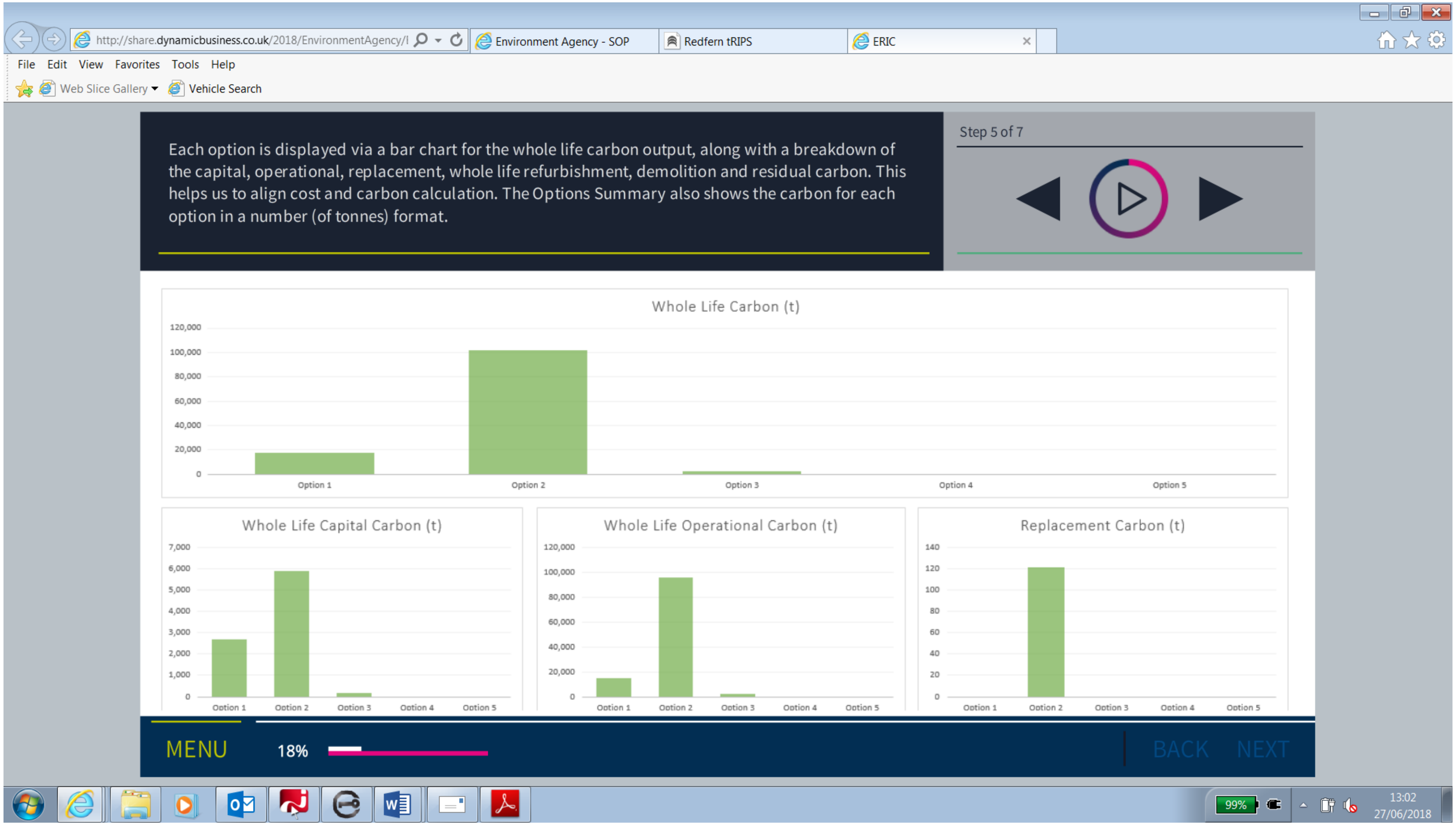


Figure 6.15 WLCPT (Eric) e-learning screen shot 2; note graphical representations refer to tone of carbon on the vertical axis and options reviewed on the horizontal axis

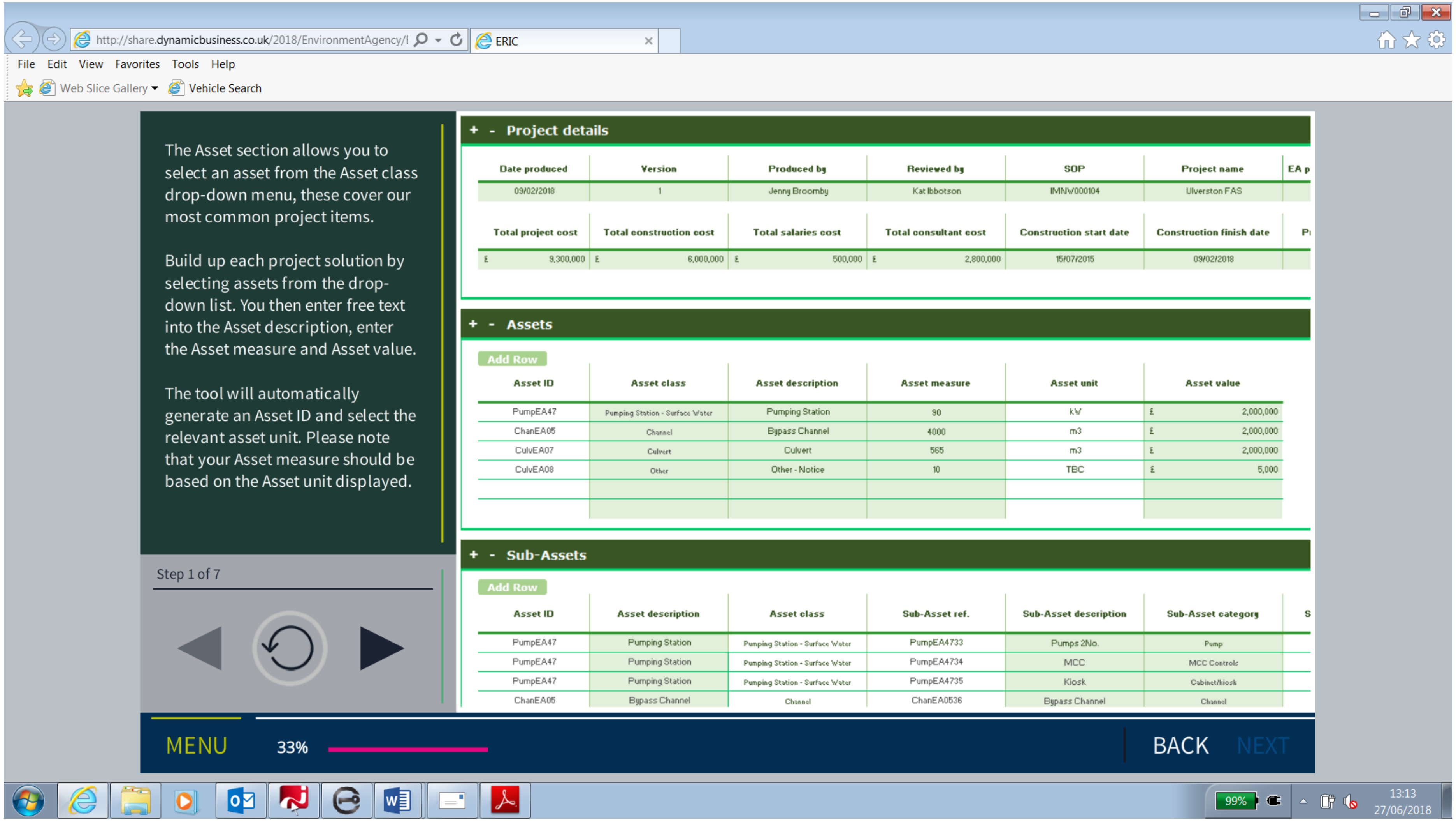


Figure 6.16 WLCPT (Eric) e-learning screen shot 3

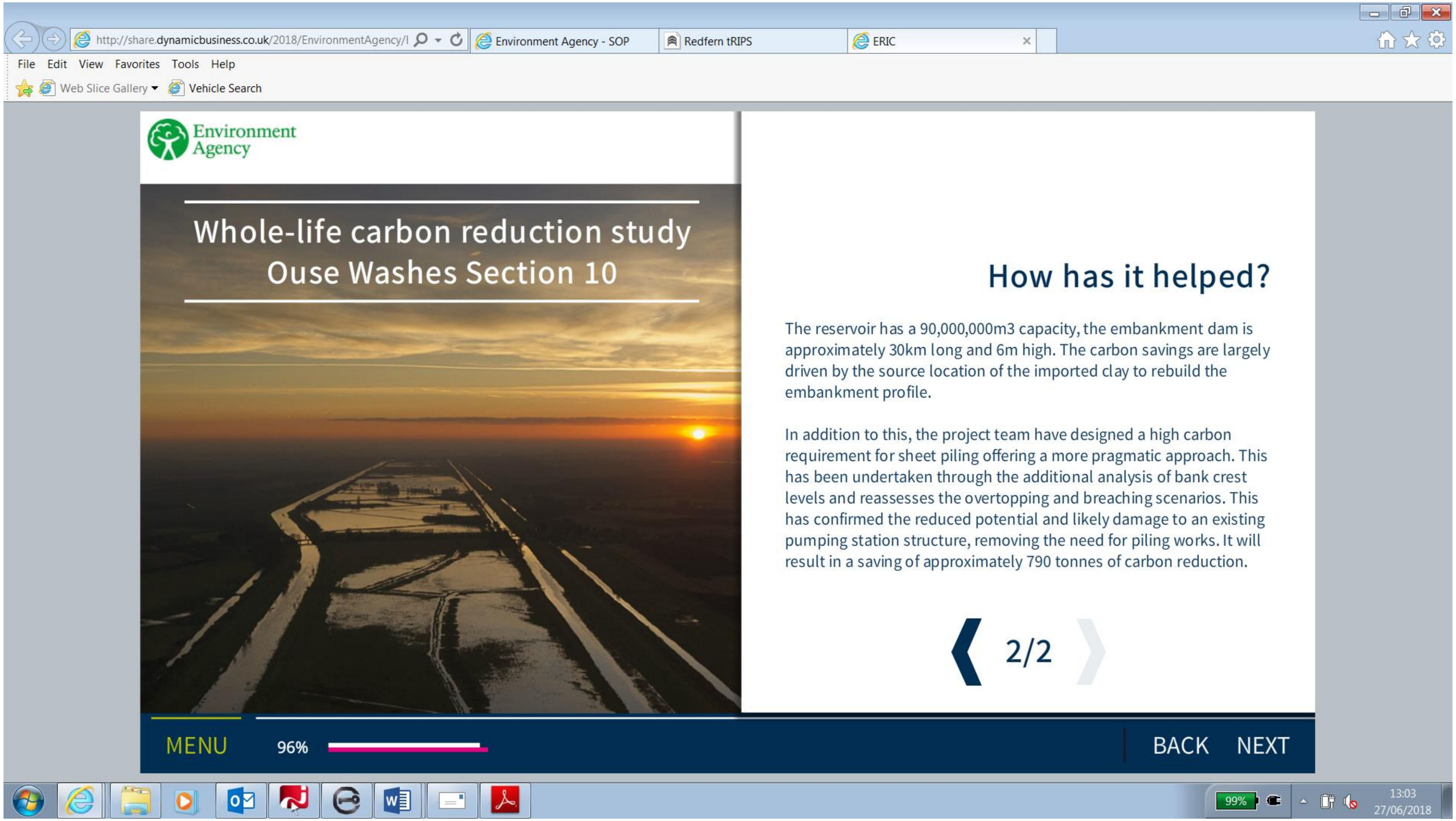


Figure 6.17 WLCPT (Eric) e-learning screen shot 4

6.7.8 Action 1: Reporting

On commencement of the Carbon Planning Manager role in August 2016, specific focus was made on establishing the outstanding carbon baselines for projects that were due to deliver construction schemes within the 2015–2020 cycle. These only looked at the single solution taken forward, as the opportunity to review other options within the appraisal stage had passed. Further information on communications and reports memo can be found in Appendix E. In reviewing this progress as an organisation, the first reporting cycle commenced in Quarter 2 (Q2) 2017; in addition to this the shadow Key Performance Indicator (KPI) 1411 was established with accountabilities for its achievement held with FCRM Area Directors. Reporting has been undertaken quarterly since this date, with improvements to data quality and the implementation of outstanding baselines, being an ongoing activity. Through the continued improvement of how data is collated and represented, it has been recognised by both the author and the organisation (via the FCRM Steering Group) that, reporting data and awareness within the organisation has matured, and how data is presented becomes more critical. As the author is accountable for the reporting, key changes have been made since its implementation in 2017; these have been as follows:

- source of project level data;
- breakdown of reported carbon data into Area and Project Delivery Units (PDU)/Collaborative Delivery Units (CDU);
- in cycle reporting and creation of the Project Delivery Unit Carbon Reduction Plans;
- carbon budget;
- carbon cost and efficiency correlation;
- carbon maturity review.

The need to evidence progress against a 40% capital carbon reduction, is an important and urgent requirement to sufficiently track the organisation's progress from the roll-out and implementation of WLCPT and the start of the e:Mission 2015-2020 plan. However, the challenges of implementing a new system, resulted in carbon data being inconsistently reported with the formal reporting delayed until Q2 2017. Initially the level of data was limited and efforts were made to appropriately identify the number of projects, establishing the CMT baseline and ensuring the reported information was meaningful. As it was a new system and process for carbon reporting challenges were raised for the MWF and MEICA frameworks, whereby carbon was not explicitly detailed within frameworks and contracts conditions. This resulted in MWF and MEICA commissions being removed from the main list of reportable projects, unless the project team and suppliers had proactively chosen to record and report carbon. Further information on the ‘Lite’ tool can be found in Section 6.7. This challenge created further administrative burdens in trying to establish the final projects list to monitor. At present this is an ongoing iterative task, but following the change of source data coming from the Area programme teams, the level of confidence in the reportable projects has significantly improved.

As the progress against the e:Mission target has progressed, the level of detail within the reporting also needed to develop. Data is presented by each FCRM Area and Project Delivery Unit. Details on supplier and Project Managers are also provided; along with details on whether the quality of the CC return is acceptable for reporting and upload to the CMT as a data point. Reasons for the increase and decrease in carbon usage are also included where possible and evidenced. As a result, the capital carbon reporting as of Q4 2018/2019 showed a return rate of 47% for CMT and 36% for CC. The reduction in Q3 2018/2019 represents the removal of the expected returns from 2015 and 2016. Table 6.7 provides the quarterly carbon expected and received data from Q2 2017-2018 to Q4 2019-2020

Table 6.7 Quarterly carbon reduction reporting results

Year	2017 - 2018			2018-2019				2019-2020			
Quarter	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Number of CMT expected	184	250	260	275	273	293	306	292	290	242	232
Number of CMT received	104	128	155	133	167	126	144	166	175	200	209
% return rate	56%	51%	60%	48%	61%	43%	47%	57%	60%	83%	90%
Number of CC expected	62	77	77	60	54	111	117	105	104	103	97
Number of CC received	20	28	33	33	35	37	42	47	55	76	84
% return rate	33%	36%	42%	55%	64%	33%	36%	45%	53%	74%	87%

A broad overview of the reporting progress, has been provided, however as the author has an organisational accountability to provide better data; the author has either directly or via supplier support, undertaken the following assurance tasks to improve data quality:

- review of all Q2 and Q3 2017/2018 submissions to ensure returns are compliant;

- acceptance of only fully completed CC from Q4 2017-2018;
- updating of all CC returns in the latest format following the Eric assurance review in Q4 2017 – 2018 (via supplier support);
- removal of all outstanding CC from the 2015 and 2016 chase list following a presentation in November 2018 to the Executive Director Team;
- utilisation of Area Programme Team project data list from Q3 2018-2018;
- carbon reporting task and finish group review Q2 2019;
- inclusion of carbon budget data within Q3 report 2019;
- Q4 2019/2020 was the final reporting undertaken by Carbon Planning Manager (author) before the process was incorporated into central reporting team as a business as usual activity.

The combination of these changes has resulted in submissions being of greater quality, with improved understanding, reduced user errors and more focus on collating CC returns that have a better chance of being submitted with good and realistic data. The variance in project numbers presents a challenge in providing a clear picture on which projects are to be included within the reporting. For this purpose, reporting refinement has been kept to projects that are completed within the 2015 to 2020 cycle.

The reporting challenges also highlighted the lack of project progress with formal reporting only via the submission of the CMT and the final CC; an overview of whether projects are on track to reduce carbon, is unknown until the final submission. At the request of the organisation's Director of Operations each Project Delivery Unit (PDU) from 2018/2019 has needed to provide a programme level Carbon Reduction Plan (CRP). Of the seven PDU hubs, the return rate has been inconsistent resulting in only six of the seven PDUs having submitted a carbon reduction plan; of this only two units have consistently submitted a return each quarter, whereby PDU6 have provided data and evidence of carbon reduction across the programme. When ascertained why and how PDU6 is significantly ahead of other units in carbon reduction it is via the proactive effort and collaboration from both the client and supply chain, ensuring that carbon reduction activities are supported by evidential data. McLennan (2019) describes this as having the right platform to create a collaborative relationship along with an 'area of mutual interest'. This is evidenced in the form of completed CMTs, CCs and in utilising wider efficiency data to establish where teams have made efficiency savings that also have a beneficial carbon reduction element (EA, 2019a).

In addition to this, the collaboration between client and supply chain, has provided internal challenge and a positive approach to carbon reduction. Items such as knowledge sharing of the PDU6 approach has been highlighted in local carbon catch up calls along with presentations at the Carbon Day in February 2019 (EA, 2019a). Local activities in collating data is undertaken in the form of a survey (EA, 2019a) provided to project teams monthly for completion, with the results utilised for the Programme Delivery Unit (PDU) Carbon Reduction Plan (CRP) reporting of progress. As of March 2019, PDU 6 had already demonstrated a 34% carbon reduction saving across this programme with a forecast of 56% by March 2020.

In reviewing the reporting challenges, two key items have been a consistent challenge and barrier to improvement. These have been:

- governance and compliance;
- ease of reporting – data from source.

It is these two areas that also impact the future progress and alignment to PAS 2080 (BSI, 2016) and has been identified in the Capital Carbon Maturity Review 2015 – 2020 (EA, 2019f) produced on behalf of the organisation by the author. This review outlines the organisation’s progress and journey in aligning its systems, processes, tools and behaviours to the PAS 2080 (BSI, 2016). It has been utilised to focus future work streams and to support wider industry knowledge share, and was submitted as an example case study for the Infrastructure Industry Innovation Partnership (i3P) Consultant Flagship Project, supported by carbon case studies and factsheets, highlighting the organisation’s knowledge share and training support.

Capital Carbon Maturity Review 2015 – 2020 (EA, 2019f) highlighted the following items requiring further improvement and development, internally highlighted as Amber (A) as part of a Red, Amber, Green (RAG) status:

- establish robust governance framework for infrastructure delivery;
- set incentives, where appropriate, to encourage desired behaviours. Management process requirements, as appropriate;
- recognise and incentivise innovative behaviours;
- review Carbon reduction performance, act on feedback and drive continuous improvement through better data collection, capturing current good practice in carbon reductions etc.;
- develop appropriate realistic baselines;
- build nothing, build less, build clever, and build efficiently.

For the first four bullet points, the establishment of changes via NGSA and CEEQUAL along with greater involvement of NEAS staff; as part of the newly created Portfolio Assurance team within the organisation, is expected to improve these PAS 2080 (BSI, 2016) focus areas. The development of appropriate realistic baselines, although there is already an established baseline quantification and reporting system in place; it is recognised by the author and organisation that improvements can be made, which has resulted in analysis being made to establish alternative carbon metrics, in the form of a carbon budget, as covered in section 6.7.5. For final bullet point, evidence is available via the case studies and factsheets where the build nothing, build less, build clever, build efficiently process has been successful. However, for projects within the 2015 – 2020 cycle, evidence is low, despite a route for reporting being available via the FCR and via case study examples.

In addressing governance and compliance the following improvement activities have been incorporated within the existing approval system:

- incorporated into central reporting team as a business as usual activity (EA, 2015b);
- carbon included within framework and contract conditions and within the delivery plan as a specific document (EA, 2020a);
- update of the 5-case business model template, with the clear requirement for carbon to be included alongside cost (EA, 2020b);
- inclusion in Gateway signoff forms/checklist (EA, 2019e).

6.8 Action 2: Prioritisation, implementation and promotion of low carbon solutions

The second action research action of prioritisation, implementation and promotion of low carbon solutions, had been identified as a key requirement within the literature (sections 2.2.1 and 2.3 to 2.6), the key concepts (Appendix A and Section 3.5 and 5.3) and has been collaborated within the survey analysis (section 7.3). The activities undertaken through the prioritisation, implementation and promotion of low carbon solutions will be used to determine whether OB9: To investigate whether low carbon promotion influences organisational culture. Embedding whole life carbon reduction in an organisation has two identifiable challenges: addressing the tools and systems and secondly leading a cultural change to ensure that the initiative embedded is a success. For the author's organisation focusing on low carbon within projects and within the wider organisation is not a new concept. However, focusing on whole life carbon reduction and changing the focus from a simple reporting aspect to a low carbon way of working, is new. Therefore, the author's carbon reduction approach to-date has very much been around tactical tasks required in implementing WLCPT to influence a cultural change within the organisation, with a focus on the duration of the current e:Mission 2015 - 2020 (EA, 2015b). However, these tactical and practical requirements have been in the context of a wider and more strategic focus, one that works towards the government's target of net zero carbon reduction by 2050. It also aligns to industry best practice and standards in the form of ICR (HM Treasury, 2013) requirements and PAS 2080 (BSI, 2016); all of which have been developed and matured over the course of this study.

According to Mayhew (2016), the strategic level focus should be on how we can create the organisational culture we want, noting that Peter Drucker (Drucker, 2011) stated 'culture eats strategy for breakfast', an organisation can have the strongest strategy, vision and focus, but poor culture will sabotage any new initiative. This is because culture is people and strategy will only ever be as good as your people. Understanding what the organisations' current culture is, in regard to low carbon is key to being able to effectively influence and change it. 'Culture is a measurable expression of a multitude of elements coming together to create how an environment is experienced by others' (Mayhew, 2016).

Organisations can decide how to influence low carbon culture by being aware of what to create but also what to allow as the key to success. All individuals have the ability to determine culture below, but not above; this is why strong and clear leadership is needed throughout the organisation, providing a consistent message on low carbon. Mayhew (2016) states there is a need to understand what an individual can control and affecting it to make a change. Culture makes people feel like they belong, it is invisible, yet it is also recognisable. It cannot be faked, culture repeats, it is consistently present, repeating the same practices over and over, becoming a habit and a normal way of working. Rewarding behaviours reinforces culture which is why avoiding non-compliance becomes a powerful enemy. The language a group uses shapes the culture of that group; talk positively about low carbon the group responds positively. 'Healthy culture can only be maintained by healthy leadership and healthy pursuant of cultural excellence' (Mayhew, 2016); this is key in terms of tactical improvements and a vision to always strive to make continuous improvements.

6.9 Action 2: Planning in order to initiate change

The author's aim is to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT); and to test: OB9: To investigate whether low carbon promotion influences organisational culture. It has required continuous improvement activities to be undertaken, aligning to industry best practice and standards which maintain an evidential approach and support the government target of net zero by 2050.

According to McNiff and Whitehead (2011) within action research, 'A theory is a set of ideas about what we claim to know and how we have come to know. If we can show that what we know (our theory) stands up to public scrutiny in relation to agreed criteria and standards of judgement, we can claim that our theory has validity (has truth value and is trustworthy)'. The prioritisation, implementation and promotion of low carbon solutions, is required in order to sustain change to an organisation's way of working. Discourse centred understanding of change, is termed the 'linguistic turn', which views language not as a passive approach which reflects or describes the world but as an 'active entity' through which the world becomes meaningful to individuals (Hughes, 2019). The author in progressing this study, has recognised the correlations between complexity theory, complex adaptive systems and action research, identifying current gaps in knowledge, whilst also recognising that author's own influence, motivation and approach, was also an important tool to be relied upon. Phelps and Hase (2002) state: 'action research has always, by very virtue of its approach, operationalised emergent processes and it hasn't shied away from complexity', the author by undertaking practical action through iterative review and feedback loops to develop, influence, create and evidence a sustained low carbon way of working within an organisation. The author has also sought to publicly validate research along with validating her own influence and society's response to climate change as a whole that has contributed to the change within the organisation. As part of WLCPT rollout; the promotion, prioritisation and implementation of low carbon solutions has been an ongoing requirement that has required both an internal and external approach. Public and professional scrutiny of WLCPT and its supporting documentation has been undertaken via three avenues:

- public promotion and communications;
- publicly available information;
- professional review and support.

In taking forward these three avenues the author has undertaken several high-profile activities in support of the wider prioritisation, implementation and promotion of low carbon solutions. These will be expanded on in following chapter sections.

6.10 Action 2: Implementing the change (acting) and observing the process of implementation and consequences – public promotion and communication

The internal validation approach has been through organisation and supply chain communication, training sessions, presentations and reporting of carbon evidence, which has been part of the overall implementation of WLCPT. The external validation approach has been through, raising awareness of the organisation, its values, its role in carbon reduction, the WLCPT available along with the promotion of the author's role within the organisation as Carbon Planning Manager and their professional credibility. Since 2015 author, has put herself forward for awards and presentations, to promote WLCPT and authors' organisational role, these are as follows:

2015

- shortlisted for Women in Construction Green Leadership Award – WLCPT as a case study

2016

- shortlisted for Women in Construction Green Leadership Award – WLCPT as a case study;

- presented at Flood and Coast 2016 – subject WLCPT
- presented at Volvo Construction Climate Challenge (CCC, 2016) (CCC, 2017) (CCC, 2016) (CCC, 2017)– subject WLCPT (Eric)

2017

- shortlisted for Women in Construction and Engineering (WICE, 2017) – Best Woman in Environment and Sustainability
- shortlisted Water Industry Achievement Award 2017 – subject implementation of WLCPT

2018

- presented at Flood and Coast 2018 – subject carbon and cost;
- shortlisted for New Civil Engineer Tech Fest awards – WLCPT (Eric) as a case study;
- judge at British Construction Industry awards – carbon category.

2019

- nominated for EA employee awards;
- presented at National Construction expo (Speakers Kat Ibbotson, 2019) – Cost and Carbon Tool as a topic;
- participation in i3P consultant flagship project – case studies, factsheets and capital carbon maturity review utilised as evidence;
- presented at the roll out of the Inventory of (embodied) carbon (ICe) database (RICS, 2019);
- presented at Flood and Coast 2019 – subject carbon and cost (Flood and Coast, 2019); secured an event stand to promote low carbon construction solutions;
- judge at British Construction Industry awards (NCE, 2019)– sustainability and environment category;
- Infrastructure Projects Authority – leading decarbonisation workshop;
- panel expert – Mott MacDonald 2019 Carbon crunch;
- Women in Engineering Society presentation/discussion (WES, 2019) – Impact of engineering on climate change;
- presentation carbon expo, February 2019 – subject ‘Where to go for carbon help and support’, December 2019 – subject ‘EA Low carbon journey’ and event stand for WLCPT promotion.

2020

- Judge at British Construction Industry Awards - (NCE, 2020);
- Judge at NCE 100 (NCE, 2020);
- ICE COP 26 Chair of work stream 1 Measuring, sharing and benchmarking carbon impacts (ICE, 2020c);
- Key note speaker, London South Bank University, Climate, Carbon, Energy and Resources Week – 23 June 2020;
- Women in Engineering Society – Winner Top 50 Women in Engineering – Sustainability June 2020 (WES, 2020);
- Contractors Declare panel discussion (Qualis Flow, 2020);
- The cost of carbon podcast (The cost of everything, 2020).

This list of awards and presentations represents author's increasing credibility within her own organisation and across industry as a leading professional in carbon reduction within UK public sector FCRM construction. The author has attained three conference proceedings and one journal paper. Further details on the internal and external communications undertaken can be found within Appendix I.

6.11 Action 2: Reflecting on processes of change and re-planning – publicly available information

In addition to publicly sharing the organisation's progress on implementing low carbon solutions within UK public sector FCRM construction, the sharing of WLCPT and supporting documents has also been undertaken since March 2016. This has resulted in 322 external registered users of WLCPT (as of September 2020), ranging from: academics; consultants; contractors, community groups and other clients from the UK and overseas. Users of WLCPT are provided a data license requesting the 'end of construction carbon calculator' to be shared back with the organisation to support updates to CMT (EA , 2016). Documents shared with external users are as follows:

- Carbon Modelling Tool (EA, 2020c);
- Carbon Calculator (EA, 2020d);

- CPT Operational Instruction (EA, 2020e);
- E-Learning link - https://ericenvironmentagency.co.uk/.

In addition to this, examples of case studies and factsheets are provided; these are:

- sprayed concrete;
- cemfree concrete;
- vacuum excavation;
- trench mix;
- hydrogen power lights;
- geosynthetic clay liners;
- precast wall;
- wall injection;
- polyurethane resin;
- pneumatic actuated gates;
- plastic piles;
- pumping station reduced operational carbon;
- clay import;
- Natural Flood Management (EA, 2019f);
    - methodology factsheet;
    - Sussex flow case study;
    - Holniote case study;
    - Tebay case study;
- limpet dam;
- brico block;
- hydroslide;
- concrete canvas;
- AACM;
- cathodic protection.

In addition to providing knowledge share information, external users are offered the opportunity to join the DEFRA Low carbon future Yammer group. As of March 2020, there are a combination of 451 internal and external users sharing low carbon knowledge.

6.11.1 Action 2: Reflecting on processes of change and re-planning – professional review and support

The development of the Carbon Planning Manager role (EA, 2017) within a complex organisation, has enabled author to undertake the action research study by implementing and promoting low carbon to have a wider and more tangible impact. The author's role and study focus has moved through differing stages since it's commencement in 2013. The opportunity and challenge to influence and evidence a change in complex organisation through the implementation of WLCPT has offered a greater opportunity and a change of research model to an action research method, with the study incorporated into the focus of e:Mission 2015 – 2020 plan, and the ability to meet the organisation's drivers for change.

Action research requires the researcher to justify claims of knowledge by the publication of authenticated evidence, and then making claims public in order to subject them to critical evaluations in order to test their validity (McNiff, 2011). This was achieved through the independent review of WLCPT (EA, 2018) and subsequent development and updates to the WLCPT and supporting guidance. The availability of training through the low carbon workshops, e-learning, case studies and factsheets (EA, 2018); the ongoing DEFRA Yammer low carbon future communications and presentations undertaken by the author. The culmination of research and practice has resulted in an organisation better prioritising low carbon and aligning to PAS 2080 (BSI, 2016). The author has undertaken a capital carbon maturity review on behalf of the organisation (EA, 2019g) and has been shared as a PAS 2080 case study for the i3P Consultant Flagship project; which is focused on improving guidance on how organisations can achieve PAS 2080 (BSI, 2019) certification status.

> *'Sustainability is at the heart of everything we do within the Environment Agency to 'Create a better place for people and the environment'. We are developing our 2030 sustainability strategy now and we are building it around the UN Sustainable Development Goals. We are focussed on the big challenges like the climate emergency we face. We want to move to be a zero-carbon organisation and ensure we have reduced our emissions as much as we can at the same time. Everyone in our organisation and our supply chain is key to this'.*
>
> Simon Dawes, Head of Sustainable Business (i3P, 2019)

It is through the authors' activities and the organisational changes implemented, that have resulted in a wider awareness and focus on carbon reduction. This has led to a greater number of individuals being part of the carbon reduction process, from: communication; assurance; change and improvement, and reporting. In addition to these low carbon initiatives, the repeatable WLCPT process, approaches and principles taken forward by CDU NEAS and supplier leads, has increase the carbon support provided (from top down and bottom up) across the organisation and supply chain (Holland, 2014). . The general awareness and wider learning of low carbon requirement is becoming embedded within the organisation, via supply chain and project teams, looking ahead the requirement and demand for more specialist support is identified through the Collaborative Support Framework (CSF) where specialist carbon support is also available. This adaptation to approach within organisation is also recognised in the increased and changed scope of work of the Carbon Planning Manager role of which the author secured as part of this research study (EA, 2017a).

6.12 Action 2: Reflecting on processes of change and re-planning – capital carbon maturity review 2015 -2020

Being able to measure the progress of an organisation through the outputs required from WLCPT only provides one linear aspect, the 'behaviour of a whole CAS is not obtained by summing the behaviours of the component agent' (Holland, 2014). As an example, the summation of the reported carbon results do not quantify the level of change, or a strategic overview as to the maturity level of the organisation in line with industry best practice. Taking this action forward author has undertaken two maturity reviews one in February 2017 (EA, 2017) and an update in March 2019 (EA, 2019g), to ascertain the overall alignment to PAS 2080 (BSI, 2016), charting the organisations journey and next areas of focus. These reports have provided a snapshot as to where the FCRM Steering Group ascertain organisations' capital carbon maturity level; these reviews have also enabled additional clarification on where the activities being taken forward are likely to support future development.

6.13 Action 1 and Action 2: acting, observing and reflecting

This action research study has enabled and empowered the author to support and influence organisational change. The justification as to why low carbon is being focused on, what are the drivers behind these decisions and why it is important to the organisation, have been part of the wider communications, and via the direct awareness raising of WLCPT. The public awareness, promotion and prioritisation of the author work has resulted in several ongoing activities that have been adapted and amended to suit the audience and the context in which WLCPT has been utilised. Reflecting on the activities undertaken:

- continued improvement of WLCPT;
    - communications;
    - continued improvement of technical element;
    - low carbon programme;
        - carbon, cost and efficiency correlation;
        - carbon budget;
        - Natural Flood Management;
    - training;
    - reporting;
- prioritisation, implementation and promotion of low carbon solutions.

It has often been a challenge to separate each activity and reflect, observe and re-plan the next approach, being ultimately entwined and reliant on each other for the overall success and embedding of WLCPT. The ultimate successful implementation WLCPT could not have been sustained without the validation of an independent review (EA, 2018). It is from this basis that the author has been able to demonstrate the suitability and appropriateness of WLCPT and challenge the cultural barriers presented within the organisation, through sound evidence and through improvements to awareness-raising and training. However, it is recognised that tools, systems and processes are not the full solution. Whereas such activities may provide an alternative way of working and improve practices, relationships and activities undertaken to achieve these 'hard' skills are supported by 'soft' skill interventions, such as: leadership at all levels, communicating a consistent message, providing continued motivation, justification, evidence and energy behind a change that empowers others to adapt. It is vital to enhance visibility of a 'Carbon Leader' such as the Carbon Planning Manager role; this is to ensure low carbon as a subject matter inside the organisation is maintained and the organisations' standing externally within UK public sector FCRM construction as a technical authority continues to develop to ensure change is sustained in the long-term.

In order to validate action 1 and action 2 activities and to further reflect on the research aim, to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT); feedback has been sought from key individuals; within the organisation, its supply chain and externally to the business. All individuals chosen have either observed the author in her work or utilised the WLCPT as part of the project process; individuals were chosen to provide a balanced, unbiased and challenging view on the author's action research activities. Three questions were asked of 24 individuals via a survey; respondents did not need to answer all three questions unless comfortable to do so. They were also asked to confirm whether their responses and/or details could be included in the author's thesis. Nine responses were received of which seven respondents agreed for their details to be included within the evidence. Further details of the responses can be found in Appendix K. The three questions asked were as follows:

- please provide your response on whether the implementation of WLCPT (Eric) has supported the prioritisation of low carbon in Flood Coastal Risk Management (FCRM);
- please provide your response on whether the wider promotion of WLCPT (Eric) and supportive training has contributed to an organisational culture change in EA and its supply chain in the context of carbon reduction in FCRM;
- please provide your response on whether author in the role of Carbon Planning Manager has successfully supported the prioritisation and promotion of low carbon in FCRM and wider industry.

Analysis and reflection of the responses will be covered in Chapter 8.

6.14 Summary and link

This chapter has set out the journey that the author has undertaken in progressing this action research study. The action research cycle, consists of five sequences:

- planning in order to initiate change;
- implementing the change (acting) and observing the process of implementation and consequences;
- reflecting on processes of change and re-planning;
- acting and observing;
- reflecting.

These stages have been utilised to demonstrate the continued reflection and improvement changes aligned to the Actions identified:

- action 1: implementation of a WLCPT and supportive training;
- action 2: prioritisation, implementation and promotion of low carbon solutions.

Chapter 7 will provide the data analyse of the survey and test the hypotheses.

CHAPTER 7: DATA ANALYSIS OF SURVEY

7.1 Introduction

Chapter 6 illustrated the conceptual framework and covers the key concepts explored along with their alignment to the study objectives. The establishment of the research problem and its refinement through this process can be found in Section 1.1 and Section 1.2; the survey method can be found in Section 4.11. This chapter covers the following areas:

- pilot survey results testing: H1; H2; H3; H4; H5 and reflection;
- main survey results testing: H1; H2; H3; H4; H5 and reflection;
- the chapter is summarised.

7.2 Pilot survey analysis

The pilot survey was carried out in August 2014. Users of the organisations Asite Project and Programme Management Tool (PPMT) were requested to undertake the pilot survey; respondents had a direct input to project delivery and comprised of: clients; design/engineering consultants; construction managers; cost consultants and other contributing parties. Of the 1000 users selected, a total of 35 returns were submitted in the three-week time-slot allocated. A further 150 automated emails were returned stating individuals were either no longer with the organisation or on long term leave. The remaining 35 surveys represented a 3.5% return rate. The pilot survey has solely been utilised to refine and narrow the research subject area and to offer improvement to the survey question approach. This is due to the very low return rate and bias results based upon the sample size.

The pilot survey comprised of the following sections: (i) background information, (ii) organisational culture and organisational leadership, and (iii) low carbon initiatives. These sections are aligned to the study hypotheses. A leading government UK public sector FCRM organisation had been identified as a key stakeholder in low carbon construction, in their primary role of client; the private sector often acts, as designer or contractor. The questions aimed to establish the views of respondents regarding their organisational and personal response to the implementation of low carbon initiatives, and the changes that maybe required. Table 3.2 provides the relationship between literature survey, objectives and pilot survey questions. VAR 1 demography of professionals has been utilised for homogeneity for VAR 2 low carbon prioritisation, this is where samples of different populations which may or may not be identical, if the populations are identical they are said to be homogeneous, and by extension, the sample data is also said to be homogeneous (OECD, 2020).

The pilot survey was analysed with the results ascertained:

- H1: the demography of professionals (VAR 1) influences low carbon prioritisation (VAR 2). Results infer, null hypotheses cannot be rejected, there is no relationship, VAR 1 does not influence VAR 2. For VAR 1, 40% were from private sector and 60% public sector, 94.0% of respondents were aged 30 and over with 84.0% of experience at 6 years and over, of this 51% were 11 years and over; 80.0% of respondents were male;
- H2: the level of organisational change (VAR 3) influences low carbon prioritisation (VAR 2). Results infer, the null hypothesis is rejected, VAR 2 does influence VAR 3. For VAR 3 respondents with low levels of organisational change replies, also had the lowest levels of low carbon prioritisation this equated to 60%. VAR 2 analysis, highlights that 86.0% (Q11) respondents viewed their organisations as about the same or better than others in the prioritisation and promotion of low carbon initiatives;
- H3: the level of organisational carbon leadership (VAR 4) influences low carbon prioritisation (VAR 2). Results infer, null hypotheses cannot be rejected, there is no relationship, VAR 4 does not influence VAR 2. In analysing data further for VAR 4, (Q10) 17.14% viewed themselves as leading on low carbon within the organisation, compared to 31.43% who didn't know and 51.43% viewed it as the role of others within the organisation, with no one person being the named organisational carbon lead. VAR 2 analysis supports this lack of clarity with limited implementation of low carbon solution 24.14%;
- H4: the quality of training (VAR 5) influences low carbon prioritisation (VAR 2). Results infer, the null hypothesis is rejected, there is a relationship, VAR 5 does influence VAR 2. Respondents with low levels of quality of training also had low carbon prioritisation, 60.0%. Where respondents had both high levels or both low levels of quality of training and low carbon prioritisation resulted in an equal score of 20.0%;

- H5: the level of organisational culture (VAR 6) influences low carbon prioritisation (VAR 2). Results infer, the null hypotheses is rejected, there is a relationship, VAR 6 influences VAR 2. Respondents with a high level of organisational culture have a lower level of low carbon prioritisation 71.34%.

Further significant relationships were identified between the following variables:

- VAR 3 organisational change and VAR 4 organisational carbon leadership;
- VAR 3 organisational change and VAR 5 quality of training;
- VAR 5 quality of training and VAR 6 organisational culture.

7.2.1 Pilot survey reflection

These results highlight existing challenges within the engineering and construction industry, with less, under 30 year old professionals being retained or attracted to work within the industry, experience is based on long term employees within the sector, leading to a more aging profession that is predominantly male, there is a recognised challenge in attracting ongoing talent in to the engineering and construction sectors.

The analysis highlighting that low carbon was not fully embedded within project delivery and that at organisation level the perception of how well, low carbon initiatives is promoted and prioritised is somewhat unfounded. This is also supported by only 42.0% actively including low carbon in the project stages (Q13), this is however deemed to be better embedded than BIM which only showed a 23.0% inclusion across project stages (Q14), challenging whether the improvements to digitalisation will also improve low carbon approaches.

Strong organisational carbon leadership did not result in low carbon prioritisation, this is against literature finding whereby PAS 2080 (BSI, 2016) and ICR (HM Treasury, 2013) both promote clear and visible organisational carbon leadership. The analysis shows only 38% of respondents we satisfied with training received (Q19) and 45% or less utilised reported or utilised lessons learnt and best practice in regards to low carbon (Q23), this demonstrates a clear gap in knowledge share and capability across the organisation.

With the response rate being extremely low a thorough review of the survey content and the population targeted offered the opportunity to further refine the research area and to focus the target audience for the main survey and improve the return rate. The field of study was narrowed down from: organisational culture; organisational leadership; low carbon; cost; BIM and efficiency to organisational culture, carbon and cost. It is recognised that all of the initial survey fields have an inter-related link in regards to low carbon initiative success. However, they are potentially research subject areas in their own right and the ability to influence or determine effective contributions to knowledge through the research study would be diminished due to the broad range identified. Feedback from respondents on the survey content, type and number of questions, resulted in statements of: 'too many questions'; too many subject areas'; 'what is the direction of the study – carbon, cost, BIM, efficiency?' In refining the survey, the number of questions covered and the level of ambiguity regarding question details, led to the change from a combination of multiple choice and free text answers, to multiple-choice only. Where applicable, questions with a similar nature were combined for multi-choice answers rather than having separate questions, reducing the overall number taken forward.

7.3 Main survey results

The main survey results are utilised to test the following hypotheses, where applicable each variable will utilise a measure tool for the multiple questions from the source data, Table 4.3 provides the relationship between literature survey, objectives and main survey questions. Table 6.2 provides the model and method utilised.

- H1: the demography of professionals (VAR 1) influences low carbon prioritisation (VAR 2);
- H2: the level of organisational change (VAR 3) influences low carbon prioritisation (VAR 2);
- H3: the level of organisational carbon leadership (VAR 4) influences low carbon prioritisation (VAR 2);
- H4: the quality of training (VAR 5) influences low carbon prioritisation (VAR 2);
- H5: the level of organisational culture (VAR 6) influence low carbon prioritisation (VAR 2);
- H6: the tonne of carbon (VAR 8) influences cost (VAR 7).

The 65 project managers from the Programme and Contract Management (PCM) department formerly National Capital Programme Management Service (NCPMS) North unit, were requested as part of their progress meetings to undertake the survey; respondents had a direct input to project delivery and comprised of team members from: client; design/engineering consultant; construction; cost consultant organisations and other contributing parties.

An average of five team members were due at each meeting; this gave a maximum expected survey return of 325 (65*5 = 325). A total of 112 returns received, 20 were incomplete, and 15 had completed or partially completed the demographic section but did not answer any further questions. In the remaining 5 incomplete surveys the demographic section was answered but only 3 questions from the next sections were finished. The incomplete 20 surveys were removed from the analysis since it was judged they could not contribute towards study findings and conclusions; the remaining 92 returns represented a 28% return rate. The results of the questionnaire provided a correlation coefficient between each variable (VAR) and a P – value (*p*) this can be found in Table 7.3.

7.4 H1: the demography of professionals (VAR 1) influences low carbon prioritisation (VAR 2)

VAR 1 demography of professionals has been utilised for homogeneity, which means the results are the same, further details can be found in Table 7.2 (OECD, 2020). Mean scores for VAR 2 are 45.09% (Table 7.3). Table 7.2 provides P-values (*p)*, for each of the demography of professionals' sections, with p set at ≤ 0.05; the main survey data is deemed correct, with only two ancillary VAR 1 influences identified, these will be discussed in Section 7.7 and Section 7.8 for:

- VAR 1 ancillary role and VAR 5 quality of training
- VAR 1 ancillary age and VAR 6 organisational culture.

In testing H1: the demography of professionals influences low carbon prioritisation, results infer, null hypotheses cannot be rejected, and VAR 1 does not influence VAR 2. A breakdown of VAR 1 can be found in Table 7.3, and VAR 2 responses can be found in Table 7.4, along with frequency of responses, columns 4 to 33 have been hidden for brevity.

Table 7.1 Main Survey correlation and P – Values

	F	G	H	I	J	K	L	M	N	O
100	Correlation									
101	VAR 2 & 3	0.38	VAR 3 & 4	-0.19	VAR 4 & 5	-0.26	VAR 5 & 6	0.28	VAR 6 & 7	0.14
102	VAR 2 & 4	-0.12	VAR 3 & 5	0.27	VAR 4 & 6	-0.26	VAR 5 & 7	0.16		
103	VAR 2 & 5	0.25	VAR 3 & 6	0.30	VAR 4 & 7	-0.01				
104	VAR 2 & 6	0.49	VAR 3 & 7	0.03						
105	VAR 2 & 7	0.32								
107	P Value									
108	VAR 2 & 3	**0.00**	VAR 3 & 4	0.10	VAR 4 & 5	**0.01**	VAR 5 & 6	**0.01**	VAR 6 & 7	0.20
109	VAR 2 & 4	0.20	VAR 3 & 5	**0.01**	VAR 4 & 6	**0.01**	VAR 5 & 7	0.20		
110	VAR 2 & 5	**0.02**	VAR 3 & 6	**0.00**	VAR 4 & 7	0.20				
111	VAR 2 & 6	**0.00**	VAR 3 & 7	0.20						
112	VAR 2 & 7	**0.01**								
113										

Table 7.2 P-Value VAR 1 demography of professionals

Main Approach		Survey											
Mean score		VAR 2 36.41%		VAR 3 45.77%		VAR 4 58.06%		VAR 5 55.00%		VAR 6 61.28%		VAR 7 60.28	
VAR 1 demography of professionals		Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value
Sector	Public n = 39	35.18	0.28	46.98	0.58	60.27	0.48	54.14	0.45	60.79	0.33	61.32	0.49
	Private n = 58	41.09		46.41		41.09		58.21		63.61		59.47	
Gender	Male n = 71	37.24	0.47	45.79	0.97	55.75	0.97	56.62	0.23	61.44	0.82	59.80	0.65
	Female n = 21	33.29		45.70		65.87		49.52		60.71		63.27	
Age	Young age n = 42	36.46	0.98	45.10	0.46	62.20	0.16	52.20	0.33	58.31	**0.04**	58.03	0.16
	Old age n = 50	36.35		46.31		54.74		57.25		63.66		63.31	
Experience	Short experience n = 45	35.85	0.82	46.34	0.51	62.31	0.10	55.00	0.98	60.08	0.50	62.60	0.26
	Long experience n = 47	36.95		45.24		53.57		55.10		61.85		58.83	
Role	Client/other n = 40	41.18	0.08	47.01	0.20	53.66	0.17	61.00	**0.02**	61.48	0.89	62.50	0.33
	supply chain n = 52	32.12		44.82		60.90		49.43		61.12		58.57	

In analysing VAR 1 and VAR 2 overall private sector scored 59% and public sector scored 41% in regards to low carbon promotion. Individual VAR 2 analysis, results highlighted:

- an equal 50% for public and private sector within Q11 for the following items
  - my organisation has low carbon targets which are applied across the organisation;
  - my organisation utilises low carbon data to prioritise/inform project options;
- private sector scored higher for:
  - my organisation has low carbon targets applied to particular customers, private sector 60%;
  - my organisation uses low carbon solutions and technologies that are shared and used by our suppliers and/or clients, private sector 56%;
  - my organisation's project leaders encourage low carbon solution and technology sharing, private sector 67%;
- public sector scored higher for:
  - my organisation receives low carbon data and information from its supply chain and/or client which allows you to bring it together with other data to promote low carbon on our projects, public sector 57%;
  - my organisation receives low carbon data and information from its supply chain and/or client which allows you to bring it together with other data to promote low carbon on our projects, public sector 67%.

Q12 low carbon planning, public sector scored highest for low carbon planning at the start of the project (56%) with private sector scoring 60% or above for all other project stages. Q13 carbon calculation, only public sector respondent stated never, within all other project stages private sector scoring 61% or above. From this analysis it could be inferred that public sector clients provide the clear leadership and project requirement at the start of the project and as the delivery of projects are largely provided by the private sector, the high scores for low carbon planning and carbon calculation would be expected at each project stage. However, the confirmation that carbon targets and the utilisation that low carbon data Q11 is utilised to inform projects is equal between private and public it could be inferred that there should also be a more even balance between the project stages since the client is the primary project manager.

Table 7.3 VAR 1 demography of professionals

	A	B	C	D	E	F
1	**VAR 1 demography of professionals**					
2		Q 1	Q2	Q3	Q4	Q5
3-4		What sector do you work for?	What gender are you?	Which category includes your age?	What is your level of experience in the UK Public Sector Flood Risk Management construction industry?	Which of the following best describes your role in UK Public Sector Flood Risk Management construction projects?
5		Private = 1, Public = 2	Male = 1, Female = 2, Prefer not to say = 3	Under 21 = 1, 21 - 29 = 2, 30 - 39 = 3, 40 - 49 = 4, 50 - 59 = 5, 60 and over = 6, Prefer not to say = 7	0 - 1 years = 1, 2 - 5 years = 2, 6 - 10 years = 3, 11 - 20 years = 4, over 20 years = 5	Stakeholder = 1, Client = 2, Design/engineering consultant = 3, Construction Manager = 4, Cost Consultant = 5, Other = 6
6	1	1	1	6	4	3
7	2	2	1	3	3	2
8	3	2	2	3	3	2
95	90	1	1	3	3	4
96	91	2	2	4	2	3
97	92	1	1	4	3	4
148	Count	92	92	92	92	92
149	Sum	129	114	356	247	329
150	Mean	1.40	1.24	3.87	2.68	3.58
151	Percentage	70	41	55	54	60
152		Countif Private =	Countif Male =	Countif Under 21 =	Countif 0 - 1 years =	Countif stakeholder =
153		55	71	0	13	1
154		Countif Public =	Countif Female =	Countif 21 - 29 =	Countif 2 - 5 years =	Countif Client =
155		37	20	7	32	26
156			Countif Prefer not to say =	Countif 30 - 39 =	Countif 6 - 10 years =	Countif Design/engineering consultant =
157			1	33	27	21
158				Countif 40 - 49 =	Countif 11 - 20 years =	Countif Construction Manager =
159				31	11	20
160				Countif 50 - 59 =	Countif over 20 years =	Countif Cost Consulant =
161				9	9	11
162				Countif 60 and over =		Countif Other =
163				10		13
164				Countif Prefer not to say =		
165				2		

Table 7.4 VAR 2 low carbon prioritisation Q11, 12 and 13 total responses

	A	J	K	R	S	Z	AA	AB	AC
1	VAR 2 low carbon prioritisation								
2	No of return	Q11 Please select as many items which to your knowledge best describe your organisation		Q12 Selecting the relevant milestones please confirm at what stage is LOW CARBON PLANNING actively discussed on your projects?		Q13 Selecting the relevant milestones please confirm at what stage is CARBON CALCULATION actively discussed on your projects?		All Q Total (Q11+Q12+Q13)	%
3		Total	%	Total	%	Total	%		
4		Q11 selection items as per countif items below		Q12 selection items as per countif items below		Q13 selection items as per countif items below			
5	1	9.00	32.14	3.00	60.00	3.00	60.00	15.00	39.47
6	2	26.00	92.86	1.00	20.00	2.00	40.00	29.00	76.32
7	3	19.00	67.86	1.00	20.00	1.00	20.00	21.00	55.26
94	90	5.00	17.86	3.00	60.00	3.00	60.00	11.00	28.95
95	91	7.00	25.00	1.00	20.00	2.00	40.00	10.00	26.32
96	92	7.00	25.00	1.00	20.00	3.00	60.00	11.00	28.95
97	Count	Total		Total		Total		All Q Total	
98	Sum								
99	Mean	10.18	36.37	1.73	34.57	1.92	38.48	13.84	36.41
00	Percentage	**36.37**	36.37	**34.57**	34.57	**38.48**	769.57	**36.41**	95.82

	J–K	R–S	Z–AA
01	Countif My organisation has low carbon targets which are applied across the organisation	Countif Never =	0.00
02	52.00	12.00	0.00
03	Countif My organisation has low carbon targets applied to particular customers	Countif At the Start of a project =	0.00
04	15.00	21.00	0.00
05	Countif My organisation uses low carbon solutions and technologies that are shared and used by our suppliers and/or clients	Countif At appraisal stage =	0.00
06	36.00	43.00	0.00
07	Countif In my organisation I find it easy to use low carbon data and information without intervention	Countif At design stage =	0.00
08	3.00	32.00	0.00
09	Countif My organisation receives low carbon data and information from its supply chain and/or client which allows you to bring it together with other data to promote low carbon on our projects	Countif At construction stage =	0.00
0	21.00	38.00	0.00
1	Countif My organisation's project leaders encourage low carbon solution and technology sharing	Countif At the end of a project =	0.00
2	36.00	13.00	0.00
3	Countif My organisation utilises low carbon data to prioritise/inform project options		
4	30.00		
5	Countif None of the above		
6	13.00		

7.5 H2: the level of organisational change (VAR 3) influences low carbon prioritisation (VAR 2)

In testing H2, the level of organisational change (VAR 3) and its influence on low carbon prioritisation (VAR 2), the following analysis has been undertaken:

- mean percentage VAR 3 45.77% and VAR 2 36.41% (Table 7.2);
- correlation coefficient +0.38 (Table 7.1);
- p-value (*p*) 0.00 (Table 7.1).

Results infer, the null hypotheses is rejected, with *p* set at ≤ 0.05; there is a relationship between organisational change and low carbon prioritisation, this supports the pilot survey findings. The correlation coefficient is +0.38; this can be classified as a low correlation (Cohen, 1996), a scatter graph can be found in Figure 7.1. VAR 3 influences VAR 2, respondents with a high level of organisational change have a lower level of low carbon prioritisation 71.34%. The results offer the opportunity to further refine the organisational change requirements in order to influence low carbon prioritisation.

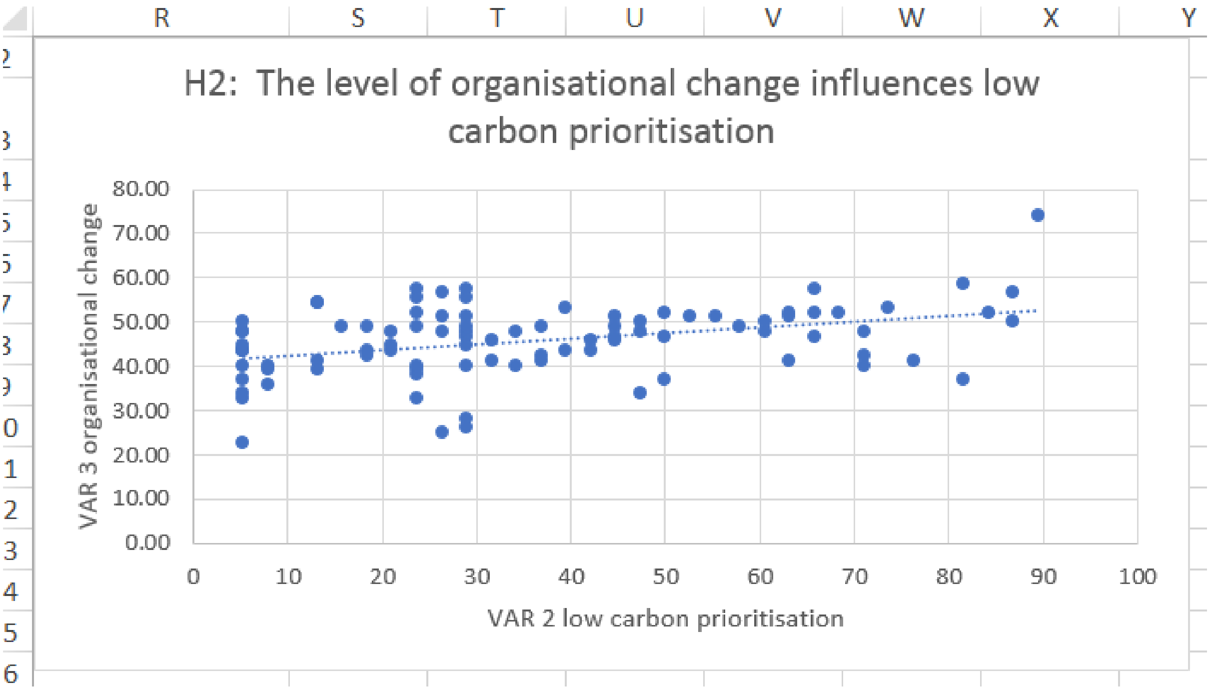


Figure 7.1 H2 scatter graph, correlation coefficient +0.38

Individual VAR 3 analysis 68.48% of respondents preferred planned change compared to 20.65% reactive and 4.35% not liking change or didn't know (Q20). This was supported by the result of 66.09% (Q19) deeming their organisation to be successful in implementing change. However, this was not reflected in the results for Q18 27.61% whereby lessons learnt and best practice for low carbon we not utilised or reported on, offering opportunities for future organisational level improvements. The requirement for improved assurance (Q16) with respondents preferring in depth regular only when there is a problem (39.13%), in depth spot checks at the beginning leading to high level spot checks regularly (22.83%) and high level regular spot checks at the beginning then reduce the frequency of checks (20.65%), is also an area for improvement in regards to low carbon submission of data and assurance of embedded processes.

VAR 2 responses highlighted that, carbon planning and carbon calculation was not included in all stages of the project lifecycle and specifically was not focused on in the early stages; this demonstrates that current practices were not in line with industry recommendations (Treasury, 2013, BIS, 2016). VAR 2 questions 12 and 13, whereby low carbon planning is highest at appraisal and construction stage (Q12), carbon calculation is highest at design and construction stage (Q13). Taking into account 'Carbon Reduction Hierarchy' (BSI, 2016), the greatest opportunity for carbon reduction can be maximised and realised at the earlier project stages. VAR 3 results scored 27.61% for the sharing and utilisation of low carbon best practice and lessons learnt (Q18), the inclusion of this data is not evident in the early project stages, and respondent results are supported by the low results for questions 12 and 13. Respondent results for question 11, respondents recognised that their organisation has carbon low carbon targets applied across the organisation (56.52%), however the remaining results are supportive of (Q18) findings for VAR 3 whereby (Q11):

- my organisation utilises low carbon data to prioritise/inform project options 32.61%;
- in my organisation I find it easy to use low carbon data and information without intervention 3.26%;
- my organisation receives low carbon data and information from its supply chain and/or client which allows you to bring it together with other data to promote low carbon on our projects 22.83%.

Further details on VAR 2 and VAR 3 analysis can be found in Appendix C. Activities for continued improvement of organisation processes will be explored through the implementation of WLCPT, via action research methodology.

7.6 H3: the level of organisational carbon leadership (VAR 4) influences low carbon prioritisation (VAR 2)

In testing H3, the level of organisational carbon leadership (VAR 4) and its influence on low carbon prioritisation (VAR 2), the following analysis has been undertaken:

- mean percentage VAR 4 58.06% and VAR 2 36.41% (Table 7.2);
- correlation coefficient -0.12 (Table 7.1);
- p-value (*p*) 0.20 (Table 7.1).

Results infer, null hypotheses cannot be rejected, with p set at ≤ 0.05; there is no relationship between organisational change and low carbon prioritisation, this supports the pilot survey findings. A scatter graph can be found in Figure 7.2. VAR 4 influences VAR 2, 71.74% of respondents have a low level of low carbon prioritisation, this consists of 42.29% with only VAR 2 under 50% and 29.35% with both VAR 2 and VAR 4 under 50%, and these are similar results to the pilot survey analysis. The results offer the opportunity to further refine the organisational carbon leadership requirements in order to influence low carbon prioritisation as part of the action research activities.

Main survey question focused on who in the organisation leads on low carbon. The results, highlighted a lack of clarity on who leads on low carbon along with a lack of individual ownership of actions. Table 7.5 provides respondent data, the high-level of participant stating 'I don't know' indicated that the visibility of who leads is not consistent or visible, and this demonstrated a lack of clarity on the leadership of low carbon initiatives. It also challenges the respondents view on prioritisation, implementation and promotion of low carbon with results in the 60-63% range (Appendix C, discussed further in Section 7.3.5). The results are indicative of low carbon being embedded into the day to day practices of the organisation and are part of the complex adaptive system, but are not fully substantiated by VAR 2 low carbon prioritisation survey results (Table 7.4) as carbon is not implemented at each project stage.

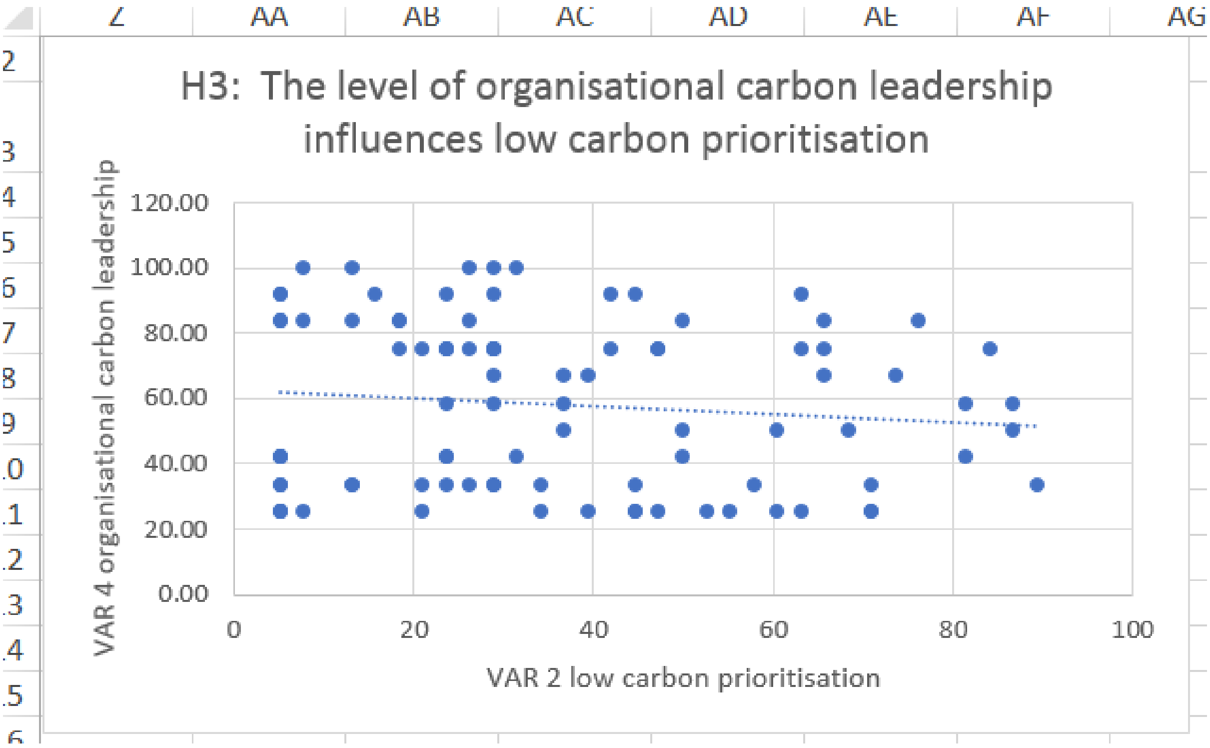


Figure 7.2 H3 scatter graph, correlation coefficient -0.12

Effective leadership is a key recommendation from the ICR (HM Treasury, 2013), the results are not in line with literature finding whereby PAS 2080 (BSI, 2016) and ICR (HM Treasury, 2013) both promote clear and visible organisational carbon leadership. However, results demonstrate that both the public and private sector respondents are unclear on who is responsible for leading on low carbon; this indicates that further work is required to ensure that there is clear leadership, responsibility and accountability.

Table 7.5 VAR 4 organisational carbon leadership

	A	B	C	D	E
1	**VAR 4 organisational carbon leadership**				
2	No of returns	Q9 Who leads on the promotion of low carbon initiatives for your organisation?	Q21 Is your organisation's response to implementing change better, worse or about the same as other Government construction sector suppliers and/or clients?	All Q Total	%
3					
4		6 = A named person, 5 = I do as part of my role, 4 = Upper management, 3 = My line manager, 2 = Another department, 1 = An external organisation, 0 = I don't know	6 = Much better, 5 = Somewhat better, 4 = Slightly better, 3 = About the same, 2 = Slightly worse, 1 = Somewhat worse, 0 = Much worse		
5	1	0	3	3	25.00
6	2	5	5	10	83.33
7	3	0	3	3	25.00
94	90	0	4	4	33.33
95	91	5	5	10	83.33
96	92	5	3	8	66.67
97	Count	92	92	All Q Total	
98	Sum	264	377		
99	Mean	2.87	4.10	6.97	58.06
00	Percentage	47.83	68.30	**58.06**	483.85
01	Median	3	4		
02	Mode	0	3		
03	Minimum	0	0		
04	Maximum	6	6		
05	Range	6	6		
06	SD	2.68	1.01		
07		Countif Upper management =	Countif Much better =		
08		25	10		
09		Countif Another department =	Countif Somewhat better =		
10		17	21		
11		Countif My line manager =	Countof Slightly better =		
12		0	29		
13		Countif A named person =	Countif About the same =		
14		9	32		
15		Count if I do =	Countif Slightly worse =		
16		1	1		
17		Countif and external organisation	Countif Somewhat worse =		
18		0	0		
19		Counti if I don't know	Countif Much worse =		
20		40	0		
21					

7.7 H4: the quality of training (VAR 5) influences low carbon prioritisation (VAR 2)

In testing H4, the quality of training (VAR 5) and its influence on low carbon prioritisation (VAR 2), the following analysis has been undertaken:

- mean percentage VAR 5 55% and VAR 2 36.41% (Table 7.2);
- correlation coefficient +0.25 (Table 7.1);
- p-value (*p*) 0.02 (Table 7.1).

Results infer, the null hypothesis is rejected, with *p* set at ≤ 0.05; there is a relationship between quality of training and low carbon prioritisation. The correlation coefficient is +0.25; this can be classified as a low correlation (Cohen, 1996), a scatter graph can be found in Figure 7.3. VAR 5 influences VAR 2, however there is not a clear distinction between VAR 5 and VAR 2 levels with 22.83% of respondents having high levels for quality of training and low carbon prioritisation, along with a similar result for low levels of quality of training and low carbon prioritisation 34.78%. The highest percentage was for high levels of quality of training and low levels of low carbon at 36.96%. The variability of this data, requires further review as part of the action research activities and will be explored further in regards to VAR 10 type of training and its influence on VAR 2 low carbon prioritisation.

Table 7.2, outlines the VAR 1 homogeneity data which indicates, VAR 5 quality of training is influenced by VAR 1, ancillary role, this is in line with literature findings whereby the role of the client is deemed to have a key role in low carbon prioritisation (Treasury, 2013, PAS 2080, 2016). For VAR 5, 55% of the survey respondents were satisfied with the level of training received, this aligns to the organisational culture levels of low carbon prioritisation, promotion and implementation. However, when compared to VAR 2 levels of low carbon prioritisation, the success in implementing industry approaches at project level, is not following best practice in embedding low carbon into decision making (HM Treasury, 2013). VAR 2 provides the percentage responses to low carbon prioritisation, of these items (Appendix C full data, Table 7.4 total data for each question).

- my organisation utilises low carbon data to prioritise/inform project options 32.61%.

The responses to question 12 (34.57%) and question 13 (38.48%), are also equally low, the stages at which low carbon planning and calculation are included within particular project stages, the results for project appraisal showed 50.80% for carbon planning and 36.63% for carbon calculation. This indicates that the link between satisfaction levels for training, utilisation of carbon data to prioritise/inform project options and the level of carbon planning and calculation undertaken at options appraisal requires further focus and clarity on what is required and how carbon data should be used, through improved quality of training. Training and skills development are required for schools, colleges and universities along with current practitioners amongst clients and their supply chains. At 55% VAR 5 quality of training, requires a more consistent and improved type of training (VAR 10), in addition to satisfaction levels. This is to ensure that individuals involved in project delivery are able to implement low carbon solutions.

For public sector organisations undertaking construction schemes, results indicate that the organisation itself needs to be influenced more than private sector supply chains. The aspiration and requirement to focus on low carbon initiatives is not at the level of priority that cost is; this is perhaps due to the need to be economically competitive (Sathre, 2007).

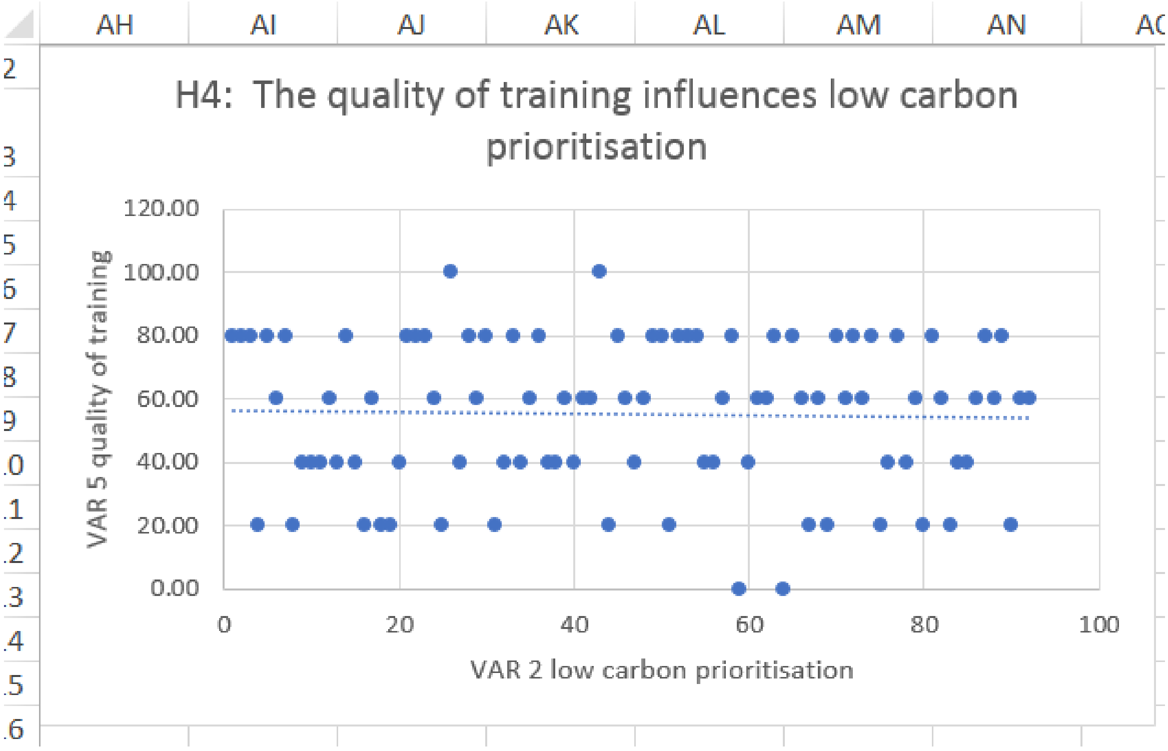


Figure 7.3 H4 scatter graph, correlation coefficient +0.25

7.8 H5: the level of organisational culture (VAR 6) influences low carbon prioritisation (VAR 2)

In testing H5, the level of organisational culture (VAR 6) and its influence on low carbon prioritisation (VAR 2), the following analysis has been undertaken:

- mean percentage VAR 6 61.28% and VAR 2 36.41% (Table 7.2);
- correlation coefficient +0.49 (Table 7.1);
- p-value (*p*) 0.00 (Table 7.1).

Results infer, the null hypothesis is rejected, with *p* set at ≤ 0.05; there is a relationship between organisational culture and low carbon prioritisation, this aligns with pilot survey findings. The correlation coefficient is +0.49; this can be classified as a modest correlation (Cohen, 1996), a scatter graph can be found in Figure 7.4. VAR 6 influences VAR 2, 58.70% of respondents have a high level of organisational culture but a low level of low carbon prioritisation, whereas 28.25% of respondents have both high levels of VAR 6 and VAR 2.

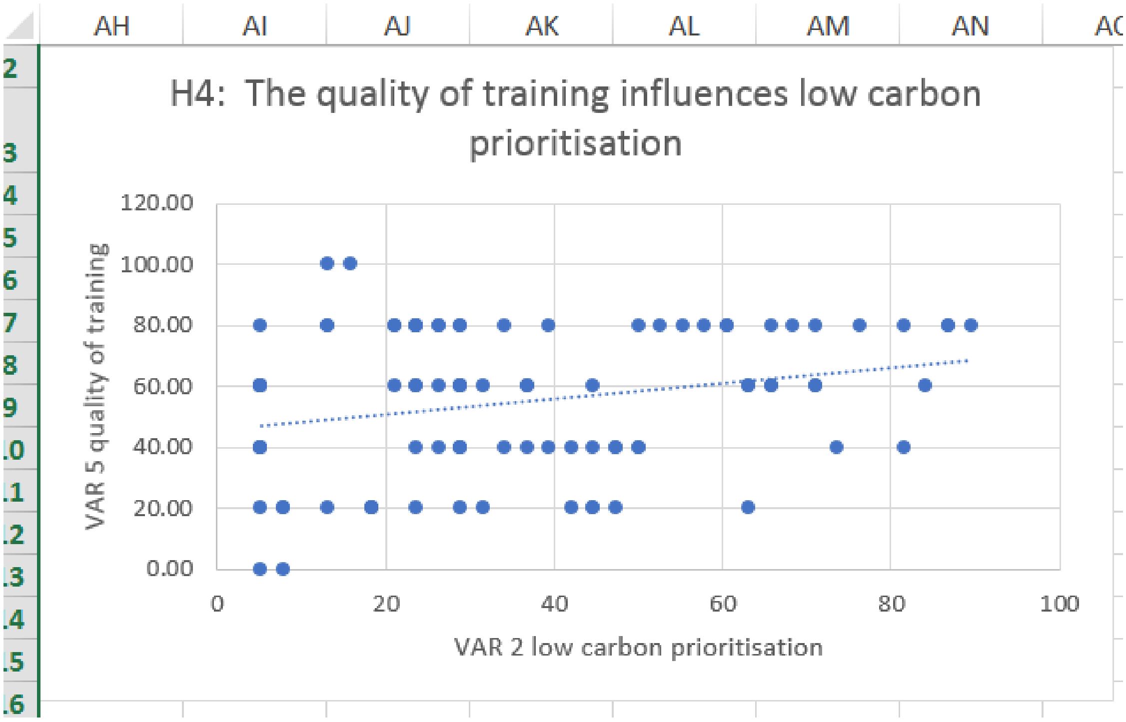


Figure 7.4 H5 scatter graph, correlation coefficient +0.49

VAR 1 homogeneity data within Table 6.4, indicates that VAR 6 is influenced by VAR 1 ancillary age. With 54% of the respondents aged 30 or over, it could be inferred that the survey results are indicative of societal representation that low carbon not a higher priority for the older generation and therefore the embedded culture of the organisation, since 51% of the respondents had an experience level of 6 or more years. This is in-line with social factors demonstrated through greater awareness of climate change challenges by society as a whole (The Guardian, 2019b). The UK construction has made many attempts to move to a ‘lean’ and innovative industry following recommendations by Farmer (2016), Industrial Strategy (HM Government, 2017a), that highlighted the need for the industry as a whole to improve. Previous attempts have been limited with Egan stating in (Wolstenholme, 2009), that ‘Since 1998 we could have had a revolution and what we’ve achieved so far is a bit of improvement’. The question then is ‘why have previous attempts at implementing change been received with enthusiasm but the results have been limited in their effect?’ The respondent results do not provide a simplistic response since the level of organisational change (VAR 3) and quality of training (VAR 5) all have a significant influence on low carbon prioritisation (VAR 2) and whereas organisational carbon leadership (VAR 4) does not. Further analysis of VAR 6 question six and seven required respondents to:

- '…indicate how important YOU believe low carbon initiatives are to YOUR ORGANISATION …', and
- '… indicate how important YOU believe low carbon initiatives are to YOU…'

These resulted in a percentage score of 75% and 74% respectively, reflecting the level of low carbon initiative importance (Appendix C).

VAR 6 question 8 asked respondents three questions on a multiple-item scale about satisfaction with how their organisation had implemented (8a), promoted (8b) and prioritised (8c) low carbon initiatives. Each question could attain a maximum of 460 (92 * 5 = 460); the result was 287/460 equivalent to 62.39% collectively. Individually satisfaction levels scored slightly satisfied and above with respondent results for how low carbon had been implemented (63%), promoted (63%) and prioritised (60%); for question 10, 71.01% viewed their organisation being somewhat better and above, in discussing low carbon on projects. Overall the collation of VAR 6 results (Q6, 7, 8 and 10) showed a combined average of 61.28%. This indicates that overall projects team members presented a positive response to how they feel their organisation implements, promotes and prioritises low carbon initiatives.

However, the VAR 2 results do not fully support this response indicating that low carbon initiatives are not as positively embedded as suggested. Low carbon planning (Q12) the score of 34.57% and low carbon calculation (Q13) 38.48%, when compared to the same question asked about cost, the results were 60% (Appendix C). Low carbon planning and carbon calculation were not consistently discussed at each project stage, carbon planning was reported as more prevalent at project start and appraisal and carbon calculation was more prevalent at design and construction and at the end of a project. Through the exclusion of 'never' from the results, cost scored higher at every stage and was also more consistently discussed across each project stage in comparison to low carbon planning and carbon calculation.

The division between public and private sectors showed that the private sector focused more on all stages across the board with cost for both public and private sector organisations receiving the main focus. This supports the literature; whereby low carbon is a soft target and cost is a hard target that is fully incorporated into contracts with a financial penalty and incentivisation elements. However, in practice, low carbon planning was only actively discussed in appraisal (50.80%) and construction stages (44.90%) followed by design

(37.81%). Indicating that the wider opportunity of reducing carbon in-line with the carbon reduction hierarchy (EA, 2018b), is not being fully realised. Carbon calculation was also focused on construction (61.44%), design (49.62%) and appraisal (36.63%). This indicated that although carbon calculation maybe accounted for the true quantification of carbon usage, it is indicating that it is primarily for reporting purposes rather than as part of the decision-making process, which is where carbon planning could be utilised. Overall respondents were satisfied with their organisations role in this area, in practice the level of low carbon prioritisation was not inline within industry best practice and does not suitably align to PAS 2080 (BSI, 2016), in regards to low carbon being planned for and calculated in the early stages of a project lifecycle in order to gain the greatest savings.

7.9 Main survey VAR correlations

Further correlation tests were undertaken for main survey responses, Table 7.1 and 7.2 provide the base data, for homogeneity, correlations and P-values. The mean percentage for VAR 7 is 60.28% and VAR 2 36.41%, the correlation coefficient +0.32 (Table 7.2), can be classified as a low correlation (Cohen, 1996), a scatter graph can be found in Figure 7.5. P-value (p) 0.01 (Table 7.2), with p set at $\leq$ 0.05; there is a relationship between cost and low carbon prioritisation. Although this does not align with pilot survey, it does with the literature findings. Cost is included within question 14 (VAR 7) of the main survey, in analysing the results 60.87% of respondents, actively discuss cost, compared to (VAR 2) question 12 low carbon planning 34.57% and question 13 carbon calculation 38.48%. Cost is considered significantly more important. Main survey question 23 provided an insight into whether respondents were in support of the ICR report which states that low carbon results in low cost (HM Treasury, 2013). The analysis of the results confirmed that 14.13% of respondents thought low carbon solutions cost more, 29.35% about the same and 56.52% viewed low carbon solutions as being less than conventional solutions. Although this is in line with industry findings and the Infrastructure Carbon Review (HM Treasury, 2013), the overall prioritisation of low carbon is not being undertaken, this is reflective in the results from H2, H3, H4 and H5 whereby low carbon prioritisation levels are consistently low.

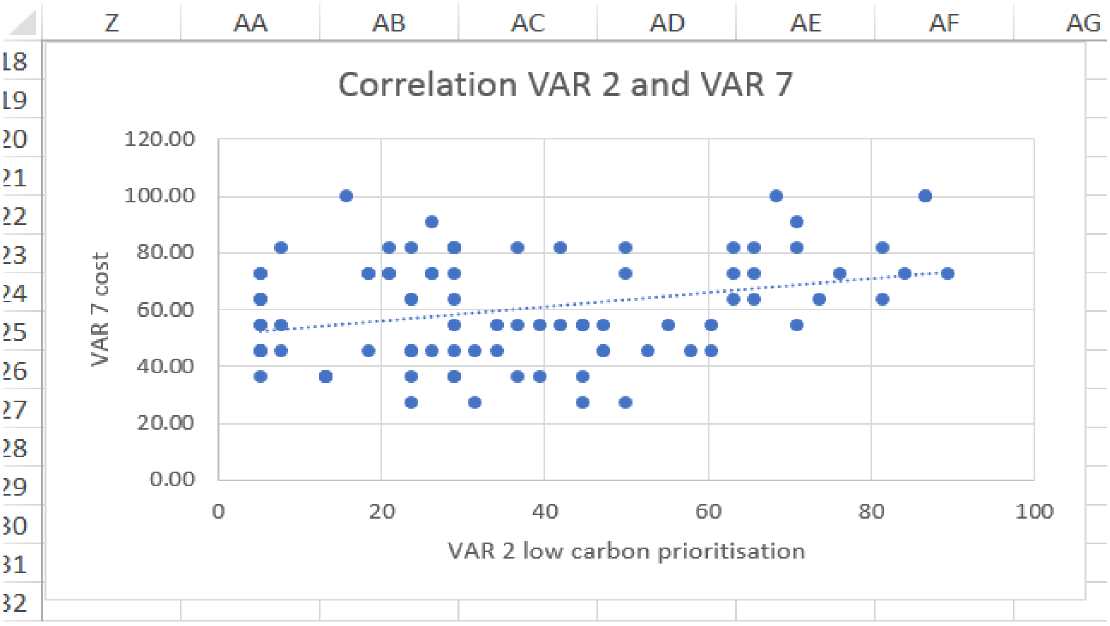


Figure 7.5 VAR 2 and VAR 7 scatter graph, correlation coefficient +0.32

For the remainder of the VAR correlations the results are summarised as follows (Cohen, 1996):

- VAR 3 organisational change has a low correlation with VAR 5 and VAR 6; with *p* set at $\leq$ 0.05; there is a relationship between organisational change (VAR 3) and quality of training (VAR 5) with *p* 0.01. There is also a relationship between organisational change (VAR 3) and organisational culture (VAR 6) with *p* 0.00;
- VAR 4 organisational carbon leadership has a low correlation with VAR 5 and VAR 6; with *p* set at $\leq$ 0.05; there is a relationship between organisational carbon leadership (VAR 4) and quality of training (VAR 5) with *p* 0.01. There is also a relationship between organisational carbon leadership (VAR 4) and organisational culture (VAR 6) with *p* 0.01;
- VAR 5 quality of training has a low correlation with VAR 6 organisational culture; with *p* set at $\leq$ 0.05; there is a relationship between quality of training (VAR 5) and organisational culture (VAR 6) with *p* 0.01;

These significant relationships are explored further as part of the action research approach. The remaining variables have a very low or low correlation and no significant relationship.

7.10 Summary and link

The pilot survey enabled the development of the research aim and objectives; the main survey has provided an opportunity to test the current client and value chain perspective in regards to low carbon and to refine the scope of the research study. Irrespective of whether it is a public or private sector organisation, low carbon is not at the same level as cost in terms of importance throughout project life cycles. There is still an inconsistent approach, along with a lack of clarity on leadership. Although for some the level of training provided is sufficient, this is not consistent, and training is an ongoing requirement to ensure that individuals involved are fully competent and compliant in their ability to promote, prioritise and implement low carbon initiatives. It is an important contribution of knowledge to learn that industry professionals indicate relatively low levels of satisfaction with the level of implementation, promotion and prioritisation of low carbon initiatives; they may be indicating a willingness to act, but frustration with a culture amongst industry leaders to prioritise cost over carbon.

To make changes, a better understanding of organisational culture, including the ethics of organisations and the effect of leadership style are required. Relationships between organisational carbon leaders and those employees involved in implementing low carbon initiatives needs to be strong. Diagnosing the organisational culture can assist in implementing the type of change needed (Burnes, 1996 and Sundar, 2013); the survey results indicate that the 'true culture' of organisations surveyed do not have consistent and repetitive processes in place that makes 'something cultural'. Sustaining a transformation in order to achieve a cultural change requires strong leadership and governance (Mayhew, 2016). Indicating that the level of reporting of low carbon at required stages within the project lifecycle is low and therefore, leadership involved in low carbon initiatives are failing to embed and sustain low carbon initiatives because they do not understand how to make them important to employees.

Further research is required to further understand the culture of organisations, from clients through to the whole value chain, and determine whether implementation, promotion and prioritisation of low carbon initiatives is business as usual, or whether additional work is required to ensure that the level of importance given to this area is consistent with that of cost.

Chapter 8 provides data analysis of the action research activities and hypotheses tested.

CHAPTER 8: DATA ANALYSIS OF ACTION RESEARCH

8.1 Introduction

Chapter 7 presents the data analysis for the survey along with the details of the hypotheses tested. The establishment of the research problem and its refinement through this process can be found in Section 1.1 and Section 1.2; the action research method can be found in Section 4.12 and Chapter 6. This chapter presents the action research data analysis and is structured as follows:

- action research objectives; hypotheses and variables.
- action 1, research results H6, H7 and H8
- action 2, research results H9
- action research feedback and reflection
- the chapter is summarised

8.2 Action research objectives (OB), hypotheses (H) and variables (VAR)

Table 4.3 provides the relationship between literature survey, objectives and main survey questions. Table 6.2 provides the model and method utilised. The action research approach comprised of two main activities, Table 8.1 provides further details on the OBs, Hs and VARs:

- action 1: Implementation of a WLCPT and supportive training
- action 2: Prioritisation, implementation and promotion of low carbon solution

Table 8.2 provides the action research correlation coefficients and p – values (*p*).

Table 8.1 Action, objectives, hypothesis and variables

	A	B	C	D	E
1	Action	Objective	Hypothesis	Variable	Action Research data
2		OB6: To investigate whether tonne of carbon influences cost	H6: The tonne of carbon influences cost	VAR 8	WLCPT carbon outputs
3				VAR 7	Projects that have both a cost and carbon submission at the end of the project.
4		OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influences cost	H7: The level of implementation the quality of implementation of a whole life carbon planning tool influence tonne of carbon	VAR 9	Comprises of the carbon data and reports from WLCPT outputs
5	Action 1			VAR 8	WLCPT carbon outputs
6		OB8: To investigate whether type of training influences tonne of carbon	H8: The type of training influences tonne of carbon;	VAR 10	Number of project managers who have completed the e-learning module; submitted a carbon return at the end of the project and applied low carbon best practice approaches
7				VAR 8	WLCPT carbon outputs
8	Action 2	OB9: To investigate whether low carbon promotion influences organisational culture	H9: The level of low carbon promotion influences organisational culture	VAR 11	Comprises of the wider awareness raising and publicising activities undertaken by the research practitioner and assessment of the organisations capital carbon journey and alignment to PAS 2080
9				VAR 6	Number of project managers who have completed the e-learning module; submitted a carbon return at the end of the project and applied low carbon best practice approaches

Table 8.2 Action Research correlation coefficients and P – values

A	B	C	D	E	F
	Correlation				
VAR 7 & 8 (25 projects)	-0.13	VAR 8 & 9 (full list)	0.15	VAR 9 & 10 (full list)	0.09
VAR 7 & 9 (25 projects)	0.18	VAR 8 & 9 (25 projects)	0.40	VAR 9 & 10 (25 projects)	0.03
VAR 7 & 10 (25 projects)	0.09	VAR 8 & 10 (full list)	0.17	VAR 9 & 11	
VAR 7 & 11 (25 projects)		VAR 8 & 10 (25 projects)	0.20		
		VAR 8 & 11			
	P - Value				
VAR 7 & 8 (25 projects)	0.20	VAR 8 & 9 (full list)	0.20	VAR 9 & 10 (full list)	0.20
VAR 7 & 9 (25 projects)	0.10	VAR 8 & 9 (25 projects)	**0.00**	VAR 9 & 10 (25 projects)	0.20
VAR 7 & 10 (25 projects)	0.20	VAR 8 & 10 (full list)	0.20	VAR 9 & 11	
VAR 7 & 11 (25 projects)		VAR 8 & 10 (25 projects)	0.10		
		VAR 8 & 11			

8.2.1 H6: the tonne of carbon (VAR 8) influences cost (VAR 7)

In testing H6, the tonne of carbon (VAR 8) and its influence on cost (VAR 7), the following analysis has been undertaken:

- mean percentage VAR 8 26% (25 projects) and VAR 7 20% (Table 8.3);
- VAR 8 44.92% (full list of 82 projects Table 8.4);
- correlation coefficient (25 projects) -0.13 (Table8.2);
- p-value (*p*) 0.2 (Table 8.2).

Results infer, null hypotheses cannot be rejected, with p set at ≤ 0.05; there is no relationship between VAR 8 tonne of carbon and VAR 7 cost, this does not support literature findings (HM Treasury, 2013). A breakdown of VAR 7 and VAR 8 for the 25 projects can be found in Table 8.3, along with frequency of responses, the following analysis was undertaken: 60.0% of projects had both a cost increase and a tonne of carbon increase, 20.0% has a cost increase and a carbon decrease and 16.0% had a cost decrease and carbon increase. VAR 7 comprised of the initial cost and final cost data and assessed whether the project has an increase or decrease in cost. 80% of projects had a cost increase, from initial to final cost. The Gateway 4 final tonne of carbon data was divided by final capital cost to provide an average tonne of carbon for each project. This was assessed against the average carbon 5.28 t CO_2 per £10k capital cost utilised for the capital carbon budget results determined that 80.0% of the 25 projects were below the average tonne of carbon metric, whereas only 35.0% had a cost decrease and were below the carbon metric average. These results from the increase and decrease in cost and the above or below average carbon metric were utilised for the VAR 7 cost analysis, further details can be found in Table 8.3.

Table 8.3 VAR 7 and VAR 8 (25 projects) responses

A	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Project number	VAR 7 Cost											VAR 8 Tonne of carbon			
	Initial Capital Cost (£k)	Final Capital Cost (£k)	Capital cost change	0 = 50% or above increase, 1 = 50% or below increase, 2 = 50% or below decrease, 3 = 50% or above decrease	%	Gateway 4 final Capital Carbon	Carbon cost Average	Capitla carbon metric 5.28 tCO_2 per £10k capital spend	%	All Total	%	Reduction in CO_2 from Carbon Budget	Reduction in CO_2 from CMT	Total	%
							Column H/Column D	0 = Above average, 1 = Below Average				<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6	<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6		
Project 3	10.00	392.00	-382.00	0.00	0.00	3163.00	8.07	1.00	100.00	1.00	25.00	0.00	6.00	6.00	50.00
Project 9	10.00	319.00	-309.00	0.00	0.00	34.00	0.11	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 10	10.00	627.00	-617.00	0.00	0.00	240.00	0.38	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 11	79.30	538.00	-458.70	0.00	0.00	93.39	0.17	1.00	100.00	1.00	25.00	2.00	2.00	4.00	33.33
Project 12	141.50	843.00	-701.50	0.00	0.00	161.65	0.19	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 13	605.90	5296.00	-4690.10	0.00	0.00	182.00	0.03	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 14	10.00	474.00	-464.00	0.00	0.00	91.68	0.19	1.00	100.00	1.00	25.00	6.00	6.00	12.00	100.00
Project 15	77.90	423.00	-345.10	0.00	0.00	426.11	1.01	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 16	952.00	5081.00	-4129.00	0.00	0.00	1714.18	0.34	1.00	100.00	1.00	25.00	3.00	6.00	9.00	75.00
Project 19	41.50	20.20	21.30	3.00	100.00	12.32	0.61	1.00	100.00	4.00	100.00	2.00	6.00	8.00	66.67
Project 20	950.00	342.00	608.00	3.00	100.00	2291.88	6.70	0.00	0.00	3.00	75.00	0.00	0.00	0.00	0.00
Project 29	29.67	1336.00	-1306.33	0.00	0.00	394.16	0.30	1.00	100.00	1.00	25.00	6.00	6.00	12.00	100.00
Project 32	10.00	3541.00	-3531.00	0.00	0.00	724.00	0.20	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 33	10.00	15.70	-5.70	0.00	0.00	31.78	2.02	1.00	100.00	1.00	25.00	2.00	2.00	4.00	33.33
Project 34	10.00	108.00	-98.00	0.00	0.00	29.00	0.27	1.00	100.00	1.00	25.00	0.00	1.00	1.00	8.33
Project 38	2839.00	25792.00	-22953.00	0.00	0.00	42422.74	1.64	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 42	653.80	3393.00	-2739.20	0.00	0.00	5059.00	1.49	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 43	811.00	385.00	426.00	3.00	100.00	6167.00	16.02	0.00	0.00	3.00	75.00	0.00	0.00	0.00	0.00
Project 53	10.00	484.00	-474.00	0.00	0.00	244.53	0.51	1.00	100.00	1.00	25.00	6.00	6.00	12.00	100.00
Project 54	10.00	191.00	-181.00	0.00	0.00	332.29	1.74	1.00	100.00	1.00	25.00	0.00	0.00	0.00	0.00
Project 62	10.00	22.62	-12.62	3.00	100.00	236.07	10.44	0.00	0.00	3.00	75.00	0.00	0.00	0.00	0.00
Project 63	10.00	22.12	-12.12	3.00	100.00	281.96	12.75	0.00	0.00	3.00	75.00	0.00	0.00	0.00	0.00
Project 69	101.90	751.00	-649.10	0.00	0.00	469.00	0.62	1.00	100.00	1.00	25.00	0.00	3.00	3.00	25.00
Project 70	10.00	1352.00	-1342.00	0.00	0.00	270.60	0.20	1.00	100.00	1.00	25.00	2.00	2.00	4.00	33.33
Project 71	10.00	2862.00	-2852.00	0.00	0.00	485.40	0.17	1.00	100.00	1.00	25.00	3.00	0.00	3.00	25.00
Count	25.00	25.00	25.00	Total		25.00	25.00	25.00	Total	Total		Total	Total	25.00	Total
Sum	7413.47	54610.64	-47197.17			65557.74	66.18	21.00						78.00	
Mean	296.54	2184.43	-1887.89	0.60	20.00	2622.31	2.65	0.84	84.00	1.44	36.00	1.28	1.84	3.12	26.00
Percentage	1186.15	8737.70	-7551.55	**20.00**	80.00	10489.24	10.59	**84.00**	8400.00	**36.00**	900.00	21.33	30.67	**26.00**	216.67
				Column F				Column J					Column P		
				Countif 0				Countif 0					Countif 0	Countif 7	Countif 11
				20.00				4.00					13.00	0.00	1.00
				Countif 1				Countif 1					Countif 1	Countif 8	Countif 12
				0.00				21.00					1.00	0.00	3.00
				Countif 2									Countif 2	Countif 8	Countif 21
				0.00									0.00	1.00	13.00
				Countif 3									Countif 3	Countif 9	Countif 22
				5.00									2.00	1.00	8.00
													Countif 4	Countif 10	
													3.00	0.00	
													Countif 5	Countif 11	
													0.00	0.00	
													Countif 6	Countif 12	
													1.00	3.00	

Analysis of VAR 8 tonne of carbon utilised the Gateway 4 final carbon output and compared the reduction from the initial carbon budget set and the carbon modelling tool (CMT) output, analysis showed that 21.33% had a reduction against the initial carbon budget set and 30.67% had a reduction against the carbon modelling tool CMT. Further details for VAR 8 25 projects can be found in Table 8.3, whereby 4% of projects had a decrease against carbon budget and CMT, 12% had a decrease against carbon budget and an increase against CMT, 52% of projects had an increase against the carbon budget but a decrease against the CMT and 32% had a decrease against both carbon budget and CMT. These results infer that the CMT optioneering process provides a suitable process for measuring carbon at options appraisal and the method for setting high level metrics early in the life cycle is still enabling project teams to make reductions with 84% having achieved this. The setting of the carbon budget shows a 44% reduction from initial budget setting, however as this metric is influenced by the initial capital cost and the challenges incurred in setting robust project cost budgets there is room to improve the wider utilisation of this method.

The data presents challenges in regards to the sample size available, along with the accuracy of project scope and costs at project inception. This is not covered within this study and requires further analysis as results do not align with the either industry guidance or the evidence gathered via action research case studies and factsheets (Appendix E), to further evidence industry guidance throughout the course of this study. In addition to this the cost, carbon and efficiency correlation (Appendix J and Section 6.7.4) which highlights that project outputs are for the majority within the low cost, low carbon and improved efficiency category. Therefore, the anomaly within this analysis is influenced by the initial costs set for the project. Building on the response and analysis from the survey, the action research activities have focused on building up evidence for FCRM construction, where the tonne of carbon influences cost as with any Complex adaptive system (CAS) the sum of the individual parts does not make the whole, (Holland, 2014), the individual outputs from each of the activities needs to be viewed holistically. Utilising the final capital cost and Gateway 4 capital carbon, VAR 7 and VAR 8 25 projects have been plotted in the carbon and cost correlation 4 box model, Figure 8.1 provides further details.

Figure 8.1 VAR 7 and VAR 8 final cost and final carbon results (25 projects)

Table 8.4 VAR 8 tonne of carbon (full 82 projects)

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**VAR 8 tonne of carbon**																
2 / 3	Project number	Gateway 1 Actual Date	Gateway 4 Actual Date	Gateway 1 - Carbon Modelling tool - Capital carbon (t)	Gateway 4 - Carbon Calculator tool -Capital carbon (t)	Carbon reduction (if minus) at Gateway 4 (t)	Capital carbon budget	Reduction required against Capital Carbon budget	% change against organisations 40% capital reduction target	Reduction in CO_2 from Carbon Budget <0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6	Total	Reduction required against CMT	% change against organisations 40% capital reduction target	Reduction in CO_2 from CMT <0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6	Total	All Total	%
4	Project 1	16/10/2006	16/11/2018	535.00	2,440.54	1,905.54	1,742.40	1,045.44	182.27%	0	0	321.00	593.63%	0	0	0	0
5	Project 2	13/11/2008	14/12/2018	4,168.00	434.00	- 3,734.00	1,636.80	982.08	-380.21%	6	100	2,500.80	-149.31%	6	100	12	100
6	Project 3	01/05/2012	02/10/2017	8,725.00	3,163.00	- 5,562.00	-	-	0.00%	0	0	5,235.00	-106.25%	6	100	6	50
33	Project 80	15/05/2018	28/09/2020	5,219.00	326.19	- 4,892.81	1,853.81	1,112.28	-439.89%	6	100	3,131.40	-156.25%	6	100	12	100
34	Project 81	15/06/2018	27/09/2019	9.32	119.70	110.38	366.96	220.18	50.13%	0	0	5.59	1973.89%	0	0	0	0
35	Project 82	17/10/2017	29/04/2019	595.00	80.78	- 514.22	472.03	283.22	-181.56%	6	100	357.00	-144.04%	6	100	12	100
36									Count	82.00	Total		Count	82.00	Total	All Total	
37									Sum	190.00			Sum	252.00			
38									Mean	2.32	38.62		Mean	3.07	51.22	5.39	44.92
39									Percentage	**38.62**	643.63		Percentage	**51.22**	853.66	**44.92**	374.32
30									Median	2.00			Median	3.00			
31									Mode	0.00			Mode	6.00			
32									Minimum	1.00			Minimum	1.00			
33									Maximum	6.00			Maximum	6.00			
34									Range	5.00			Range	5.00			
35									SD	2.37			SD	2.73			
36									Countif <0 =	32			Countif <0 =	29			
37									Countif 0 =	4			Countif 0 =	5			
38									Countif 1 - 10 =	15			Countif 1 - 10 =	6			
39									Countif 10 - 20 =	6			Countif 10 - 20 =	3			
00									Countif 20-30 =	4			Countif 20-30 =	3			
01									Countif 30-40 =	4			Countif 30-40 =	2			
02									Countif > 40 =	17			Countif > 40 =	34			
03																	

VAR 8 tonne of carbon has data available across all 82 projects, Table 8.4 provides the total VAR 8 data set rows 7 to 82 have been hidden for brevity, data includes the Gateway 1 CMT assessment submitted at Strategic Outline Case (or Outline Business Case) and the Gateway 4 Carbon Calculator (CC) assessment submitted at the end of construction. The change in tonnes of carbon is analysed against the organisational target of 40% (between Gateway 1 and Gateway 4) to determine the change in tonne of carbon associated with each project, resulting in 51.22% making a reduction in tonne of carbon. Whereas, 38.62% of projects reduced carbon based on the carbon budget metric.

8.2.2 H7: the level of quality of implementation of a whole life carbon planning tool (WLCPT) (VAR 9) influences the tonne of carbon (VAR 8)

In testing H7, the level of quality of implementation of a WLCPT (VAR 9) influences tonne of carbon (VAR 8), the following analysis has been undertaken:

- mean percentage (full 82 projects) VAR 9 11.95% (Table 8.5) and VAR 8 44.92% (Table 8.4);
- mean percentage (25 projects) VAR 9 42.67% and VAR 8 26% (Appendix H);
- correlation coefficient (full 82 projects) +0.15 (Table 8.2);
- correlation coefficient (25 projects) +0.40 (Table 8.2);
- p-value (*p*) (full 82 projects) 0.20 (Table 8.2)
- p-value (*p*) (25 projects) 0.00 (Table 8.2).

Results infer, null hypotheses cannot be rejected, with p set at ≤ 0.05; there is no relationship between (full 82 projects) VAR 9 quality of implementation of a WLCPT and VAR 8 tonne of carbon. VAR 9 influences VAR 8, 47.56% had a high level of tonne of carbon (carbon decrease) and a low level of quality of implementation of WLCPT. The same result 47.56% occurred for both a low level of VAR 8 (carbon increase) and VAR 9. For the full project list, a mean score of 35.22% is representative of VAR 8 and VAR 9 combined totals, inferring that a 3rd of the projects the quality of implementation for WLCPT had an influence on the tonne of carbon the project produced. Analysis of the data infers that through the course of this action research study the level of quality of implementation of WLCPT is determined by the stage of the project was at when implementing the WLCPT (Eric), the collective action of the project team in making low carbon decisions and individual project managers level of governance and compliance in managing suppliers and contracts where carbon data should have been returned. With 41.46% having a negative or zero impact on the organisations 40% carbon reduction target (Table 8.3), this represented 34 projects of which, 11/34 projects contributed to the VAR 9 score of 11.95% (Table 8.5). VAR 9 quality of implementation of WLCPT does not automatically result in tonne of carbon reduction, however based on the very low mean score it cannot be viewed as conclusive due to the limitations of the data, the questions covered and the maturity of the embedded WLCPT process.

VAR 9 the level of quality implementation of WLCPT utilises the items required for reporting; the analysis is as follows (full 82 projects list):

- multiple options reviewed in the CMT 23.17%;
- lowest option selected in the CMT 3.66%;
- COR received 15.85%;
- CC at Gateway 3 received 9.76%;
- FCR received 7.32%.

As per the Action research timeline Appendix D, the WLCPT was not considered mandatory until April 2016, completion of retrospective CMTs was undertaken in 2017, resulting in many live projects at Outline Business Case or Full Business Case and construction stage having only one option included in the CMT and this not being considered as the lowest carbon option, in support of CMT completion retrospective CMT updates were not supported by the completion of COR. The data however does indicate that change does not embed quickly this, and also reflects the results from H2: the level of organisational change influences low carbon prioritisation, where respondents with a high level of change have a low level of low carbon prioritisation. The action research continued improvement activities and the corresponding timeline (Appendix D), the initial rollout in April 2015, was a planned change alongside the implementation of e:Mission 2015-2020. Through the review of results, a change to mandatory implementation for capital projects and frameworks, the assurance activities moved from, (Q16 Main survey, (Section 6.3.2) in-depth regular when there was a problem at the start of the implementation to a mix of high level regular spot checks at the beginning and in-depth spot check at the beginning to high level and reduced frequency rates alongside the continued improvement activities, further information can be found in Chapter 6 from Section 6.7 onwards. H7 findings are also supported by VAR 11 low carbon promotion and the Capital

Carbon Maturity Review, where by findings show Governance and compliance to be one of the main challenges (EA, 2019g).

For the 25 projects analysed (in alignment with projects identified in VAR 7 cost) results infer, reject the null hypotheses, with p set at ≤ 0.05; there is a relationship between quality of implementation of a WLCPT and tonne of carbon. The correlation coefficient is +0.40 for the 25 projects; this can be classified as a moderate correlation (Cohen, 1996). This data however is only a small sample size and therefore the full project list provides a more robust result.

Table 8.5 VAR 9 quality of implementation of a WLCPT (full 82 projects)

	T	U	V	W	X	Y	Z	AA	AB	AC
1	**VAR 9 quality of implementation of a whole life carbon planning tool**								**VAR 8 and VAR 9 Total**	
2	Project	Multi options reviewed in CMT	Lowest option selected in CMT	COR received	GW3 CC received	FCR received	Total	%	Total	%
3		0 = no, 1 = yes								
4	Project 1	0	0	0	0	1	1.00	20.00	1.00	5.88
5	Project 2	0	0	0	0	0	0.00	0.00	12.00	70.59
6	Project 3	0	0	0	0	0	0.00	0.00	6.00	35.29
83	Project 80	1	0	0	0	0	1.00	20.00	13.00	76.47
84	Project 81	0	0	0	0	0	0.00	0.00	0.00	0.00
85	Project 82	0	0	0	0	0	0.00	0.00	12.00	70.59
86	Count	82.00	82.00	82.00	82.00	82.00	Total		VAR 8 and VAR 9 Total	
87	Sum	19.00	3.00	13.00	8.00	6.00				
88	Mean	0.23	0.04	0.16	0.10	0.07	0.60	11.95	5.99	35.22
89	Percentage	23.17	3.66	15.85	9.76	7.32	**11.95**	239.02	**35.22**	704.45
95	SD	0.42	0.19	0.37	0.30	0.26				

8.2.3 H8: the type of training (VAR 10) influences tonne of carbon (VAR 8)

In testing H8, the type of training (VAR 10) influences tonne of carbon (VAR 8), the following analysis has been undertaken:

- mean percentage (full 82 projects) VAR 10 62.20% and VAR 8 44.92% (Table 8.6);
- mean percentage (25 projects) VAR 10 62% and VAR 8 26% (Table 8.7);
- correlation coefficient (full 82 projects) +0.17 (Table 8.2);
- correlation coefficient (25 projects) 0.20 (Table 8.2);
- p-value (p) (full 82 projects) 0.20 (Table 8.2);
- p-value (p) (25 projects) 0.10 (Table 8.2).

Results infer, null hypotheses cannot be rejected, with p set at ≤ 0.05; there is no relationship between VAR 10 type of training and VAR 8 tonne of carbon. Utilising the full 82 projects for analysis, VAR 10 influences VAR 8; 35.37% of respondents have both a high level type of training (e-learning) and tonne of carbon (carbon decrease), this is similar to 23.17% of respondents have both a low level type of training and tonne of carbon (carbon increase), the variability of this data is challenged further whereby a similar level of respondents 26.83% have a low level of tonne of carbon (carbon increase) but a high level of type of training. When comparing these results with the 25 projects for analysis, there is no relationship between VAR 10 and VAR 8; 56% of respondents had a low level of tonne of carbon (carbon increase) and a high level of type of training. Where type of training VAR 10 accounted for e-learning and the implementation of low carbon best practices (utilising the case studies and factsheets and low carbon solution workshops).

The sample size 82 projects (e-learning) and 25 project (e-learning and implementation of low carbon best practice) remain a challenge and as per the challenges with H7 (Section 8.3.3) the timing of the training roll out and the stage each project was at when organisation staff and their supply chain undertook the training, will result in a reduced affect, further analysis in this area is required to validate the research findings with a greater number of projects available for review. Author recognises that through the action research Action 1, the implementation of the WLCPT and the focused-on training, requirements have change during the study duration. With author initially undertaking WebEx and f-2-f training, this has continually improved with the implementation of specific: e-learning modules; low carbon solution workshops; knowledge share documents in the form of case studies and factsheets. The WLCPT (Eric) e-learning is focused on the utilisation of the tool, the purpose of why it is available, how and where to use it and how it can support the quantification of low carbon decisions and approaches. The application of low carbon best practice approaches, builds upon the low carbon solutions workshops and case studies and factsheets and provides practical examples for teams to use and challenge existing solutions. Neither is deemed to be better or worse but is aimed at addressing different learning styles and to provide multiple opportunities to promote, prioritise and implement low carbon solutions.

Table 8.6 VAR 8 and VAR 10 (full 82 projects, e-learning only)

	B	K	L	O	P	Q	R	AE	AF	AG	AH
1		VAR 8 tonne of carbon						VAR 10 type of training		VAR 8 and VAR 10 Total	
2	Project number	Reduction in CO_2 from Carbon Budget	Total	Reduction in CO_2 from CMT	Total	All Total	%	WLCPT (Eric) e-learning completed	%	Total	%
3		<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6		<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6				0 = No 1 = Yes			
4	Project 1	0	0	0	0	0	0	1	100.00	1.00	7.69
5	Project 2	6	100	6	100	12	100	1	100.00	13.00	100.00
6	Project 3	0	0	6	100	6	50	1	100.00	7.00	53.85
83	Project 80	6	100	6	100	12	100	0	0.00	12.00	92.31
84	Project 81	0	0	0	0	0	0	0	0.00	0.00	0.00
85	Project 82	6	100	6	100	12	100	0	0.00	12.00	92.31
86	Count	82.00	Total	82.00	Total	All Total		82.00	Total	Total	
87	Sum	190.00		252.00				51.00			
88	Mean	2.32	38.62	3.07	51.22	5.39	44.92	0.62	62.20	6.01	46.25
89	Percentage	**38.62**	643.63	**51.22**	853.66	**44.92**	374.32	**62.20**	6219.51	**46.25**	4624.77
90	Median	2.00		3.00				Countif No =			
91	Mode	0.00		6.00				31			
92	Minimum	1.00		1.00				Countif Yes =			
93	Maximum	6.00		6.00				51			
94	Range	5.00		5.00							
95	SD	2.37		2.73							
96	Countif <0 =	32		29							
97	Countif 0 =	4		5							
98	Countif 1 - 10 =	15		6							
99	Countif 10 - 20 =	6		3							
100	Countif 20-30 =	4		3							
101	Countif 30-40 =	4		2							
102	Countif > 40 =	17		34							

Table 8.7 VAR 8 and VAR 10 (25 projects, e-learning and best practice approaches)

	VAR 8 Tonne of carbon				VAR 10 type of training															
											Best Practice approaches									
Project number	Reduction in CO_2 from Carbon Budget	Reduction in CO_2 from CMT	Total	%	Has the Eric e-Learning completed ?	%	Has Best practice learning been implemented	%	All Training Total	%	Alternative materials	Asset repair	Optimised design to inform alternative construction methods	Materials and waste management	Efficient construction	Innovative techniques	Natural flood management	No best practice identified	Total	%
	<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6	<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6			0 = No, 1 = Yes		0 = No, 1 = Yes				0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	1 = No		
Project 3	0.00	6.00	6.00	50.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
Project 9	0.00	0.00	0.00	0.00	0.00	0.00	1.00	100.00	1.00	50.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
Project 10	0.00	0.00	0.00	0.00	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 11	2.00	2.00	4.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 12	0.00	0.00	0.00	0.00	0.00	0.00	1.00	100.00	1.00	50.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 13	0.00	0.00	0.00	0.00	0.00	0.00	1.00	100.00	1.00	50.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 14	6.00	6.00	12.00	100.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 15	0.00	0.00	0.00	0.00	0.00	0.00	1.00	100.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 16	3.00	6.00	9.00	75.00	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 19	2.00	6.00	8.00	66.67	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 20	0.00	0.00	0.00	0.00	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 29	6.00	6.00	12.00	100.00	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 32	0.00	0.00	0.00	0.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
Project 33	2.00	2.00	4.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 34	0.00	1.00	1.00	8.33	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	3.00	42.86
Project 42	0.00	0.00	0.00	0.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
Project 43	0.00	0.00	0.00	0.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 53	6.00	6.00	12.00	100.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 54	0.00	0.00	0.00	0.00	0.00	0.00	1.00	100.00	1.00	50.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	3.00	42.86
Project 62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
Project 63	0.00	0.00	0.00	0.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 69	0.00	3.00	3.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 70	2.00	2.00	4.00	33.33	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
Project 71	3.00	0.00	3.00	25.00	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	4.00	57.14
Count	Total	Total	25.00	Total	25.00	Total	25.00	Total	Total		25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	Total	
Sum			78.00		15.00		16.00				0.00	13.00	2.00	11.00	2.00	0.00	0.00	8.00		
Mean	1.28	1.84	3.12	26.00	0.60	60.00	0.64	64.00	1.24	62.00	0.00	0.52	0.08	0.44	0.08	0.00	0.00	0.32	1.44	20.57
Percentage	21.33	30.67	**26.00**	216.67	**60.00**	6000.00	**64.00**	6400.00	**62.00**	3100.00	0.00	52.00	8.00	44.00	8.00	0.00	0.00	32.00	**20.57**	293.88

Analysis of VAR 10 type of training, in establishing whether best practice techniques were implemented, information was gathered for the e-learning completion through the identification of individual PMs against project details and comparing this to the organisations Learning Zone completion report. The completion information only is utilised in the analysis and no personal data is held. For the low carbon best practice implemented, a survey was sent to PMs who had submitted a final CC, the initial request response rate for the 82 projects was 5, and following encouragement for PMs to complete the survey 33 returned data, 7 were incomplete and did not provide the project details, the remaining 25 were included within the analysis and aligned to the cost data available (VAR 7). Table 8.6 provides further details.

The low carbon solutions workshop training undertaken as part of the action 1 (Chapter 6), provides further insight as to whether the right low carbon solution decisions were made, rather than a representation of whether the WLCPT was completed adequately and data reported. Analysis of this data allows determination of whether low carbon best practice approaches were implemented. The practice types are as identified within the assurance review and within the case studies and factsheets provided as part of the low carbon solutions workshops. These were as follows (EA, 2018b):

- alternative materials – this has largely focussed on the use of recycled plastics and trial of AACM (Cemfree)
- asset repair – multiple repair techniques and products identified with significant savings where applied.
- optimised design to inform alternative construction methods – multiple examples of embankment and reservoir design optimisation to reduce volumes of material imported or transported on site.
- materials and waste management – multiple examples of avoiding disturbing contaminated land, reusing contaminated arisings, reducing transport distances, and minimising waste produced.
- efficient construction – main areas found are use of pre-cast catalogue products such as Brico Bloc and Redi-roc blocks.
- innovative technologies – generally one off or limited applications e.g. inflatable weir and hydroslide technologies.

The survey picked up on the innovation techniques above and the items identified within the case studies (Natural Flood Management) the results highlighted that Asset Repair (52.0%) and Materials and Waste Management (44.0%), were more commonly implemented, these results are expected, in part due to the nature of FCRM construction works, whereby works range from new build to asset repair. The utilisation and implementation of site waste management plans are also considered standard practice. Efficient construction and Optimised design to inform alternative construction methods, scored 8.0%, since government efficiency initiatives and lean construction techniques have been in place for some time this result appears low. The following items had a response of zero:

- alternative materials;
- innovative techniques;
- Natural Flood Management.

Case studies and factsheets, were produced from existing government public sector completed projects, results infer that embedding and sustaining, 'business as usual' low carbon solutions, requires further review. Action research activities within the low carbon future programme (Section 6.7.3) include updating minimum technical requirements (MTR), the results and influence this may have has not been captured within the action research analysis, but is identified as a key change for future improvement and training.

When analysing VAR 8 tonne of carbon against the date that the CC were submitted the following analysis was undertaken, via a control chart within Excel. Figure 8.2 provides the outputs of this analysis. The test results for the individual value show that 2 points reach or exceed the Upper Control Limit (UCL) which is set at 3.00 standard deviations from the centre line. The first point represented project number 6 which had as <0 carbon increase against the carbon budget and CMT. Its project manager completed the WLCPT (Eric) e-learning but no data was provided for any low carbon best practice implemented. In addition to this a result of 0 was scored for VAR 9 quality of implementation of WLCPT. The second point represented project number 7 which had a >40% reduction against the carbon budget and a 20-30% reduction against the CMT. Its project manager did not complete the WLCPT (Eric) e-learning and no data was provided for any low carbon best practice implemented. For VAR 9 quality of implementation of WLCPT the COR had been submitted. The significance of the nearing and crossing of the upper control limit is that it occurred between in March and June 2017. When reviewing the timeline of action research activities undertaken the following areas are highlighted:

- increased communications, presentations and workshops by author from March 2016; continuing as an ongoing activity;
- mandatory implementation of WLCPT from March 2016;
- supplier presentations and conferences June, September and November 2016;
- setting of carbon baselines November 2016;
- naming carbon tool, December 2016;
- promotional material January 2017;
- Flood and Coast presentation February 2017.

Although the specific activities cannot be individually attributed to the changes since project number 7 exceeded the UCL, and the number of projects that are near the mean or have reported a carbon reduction since June 2017, it can be inferred that project teams have a greater focus on carbon reduction within their projects due to their own increased awareness of WLCPT, and its organisational culture influence.

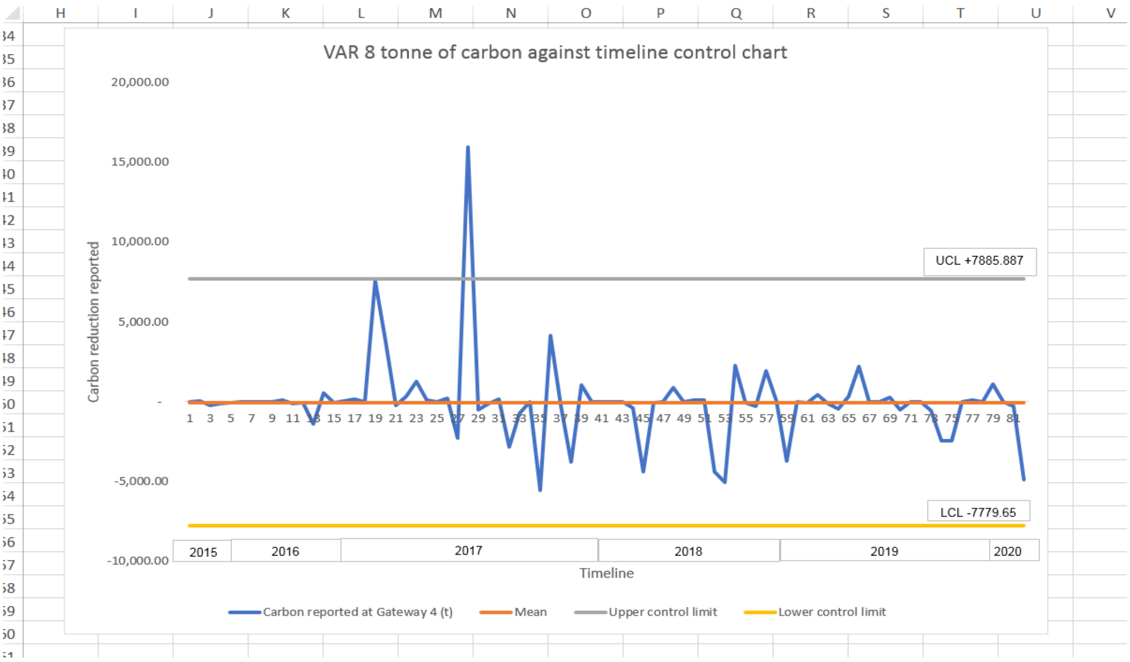


Figure 8.2 Control chart in Excel VAR 8

8.3 Action Research VAR correlations

Further correlation tests were undertaken for action research action 1 outputs, Table 8.2 provides the respective correlations and P-values. For the remainder of the VAR correlations the results are summarised as follows (Cohen, 1996):

- VAR 7 cost has a very low correlation with VAR 9 quality of implementation of a WLCPT; with *p* set at ≤ 0.05; there is no relationship between cost (VAR 7) and quality of implementation of a WLCPT (VAR 9) with *p* 0.2;
- VAR 7 cost has a very low correlation with VAR 10 type of training; with *p* set at ≤ 0.05; there is no relationship between cost (VAR 7) and type of training (VAR 10) with *p* 0.2;
- VAR 9 quality of implementation of a WLCPT has a very low correlation with VAR 10 type of training; with *p* set at ≤ 0.05; there is no relationship between cost (VAR 7) and type of training (VAR 10) with *p* 0.2.
- VAR 9 quality of implementation of a WLCPT has a very low correlation with VAR 10 type of training; with *p* set at ≤ 0.05; there is no relationship between cost (VAR 7) and type of training (VAR 10) with *p* 0.2.

8.4 Action 2: research results H9

The action research data to be utilised for the testing of: H9, is via Action 2: Promotion of low carbon and its output Capital Carbon Maturity Review 2015 – 2020 report (EA, 2019g), the following sections provide further details.

8.4.1 H9: the level of low carbon promotion (VAR11) influences organisational culture (VAR 6)

VAR 6 organisational culture within the action research element of the study has been, tested utilising the Capital Carbon Maturity Review, ascertaining the organisations alignment to industry best practice PAS 2080 (BSI, 2016). When comparing the continued improvement implemented between the first Capital Carbon Maturity Review (EA, 2017) and the second review (EA, 2019g), the following areas reviewed by author were deemed have not changed due to either consistent application or level of maturity:

- carbon reduction hierarchy - identify carbon hotspots in existing asset operation and opportunities for reduction
- quantification - identify appropriate data sources
- reporting - define reporting requirements and communicate through the value chain

The two key areas that had demonstrated further organisational change were:

- leadership and governance;
- target setting/baselines/monitoring.

Results infer, reject the null hypotheses; there is a relationship between low carbon promotion and organisational culture. VAR 11 low carbon promotion and VAR 6 organisational culture are evidenced by the activities undertaken and the author in applying subjective judgement, which deems that there is an indicative change to test H9: the level of low carbon promotion influences organisational culture. The organisation has proactively aligned its low carbon activities to PAS 2080 (BSI, 2016) and included within the Next Generation Supplier Arrangement Framework (NGSA) conditions that its supply chain partners should also align to PAS 2080 (BSI, 2016). Organisational e:Mission 2015-2020 plan had a 40% capital carbon and 45% operational carbon reduction target, it's new e:Mission 2030 is inclusive of net zero publicly validated commitment by 2030 and absolute zero by 2050 for the whole organisation (HM Government, 2019i). The increasing investment in low carbon tools, approaches and resource since 2015 has resulted in the authors Carbon Planning Manager role being established alongside the wider commitment across the organisation that carbon reduction is part of everyone's role.

Through each continual improvement activity an incremental or significant low carbon promotion has occurred alongside the incremental or significant change in organisational culture, each variable has had a constant influence and affect over the other, neither is leading nor dominant, but are reliant on each other to achieve the hypothesis that the level of low carbon promotion influences organisational culture. Within a complex adaptive system and complex organisation a continued loop of recirculating signals from VAR 11 low carbon promotion to VAR 6 organisational culture occurs, each loop provides the opportunity for negative and positive feedback; creating possible 'subroutines' that are linked to the main activity but are modulated by the surrounding activity rather than being completely controlled by it (Holland, 2014). Further details on the activities undertaken can be found in Chapter 6 and Appendix D, E, I and J. An example of this is the introduction of Carbon reduction plan within each Project Delivery Unit (PDU) to support reporting, and evidencing of carbon reduction decisions and data. As identified in Section 6.7.8, not all PDUs took forward this action, those that did evidenced a 'subroutine' of data gathering, collaboration, prioritisation and promotion of low carbon within the PDU. The results highlighted a collective improvement within the PDU at both a project and programme level along with raised awareness and compliance in attending internal training sessions. This way of working was also more widely promoted at the Carbon Expo undertaken by the organisation in February 2019, with the session being delivered by a key supplier rather than the host organisation and again in December 2019, where sessions were delivered by external organisations, with similar values and ambitions. The level of ownership within each PDU resulted in the empowerment to run internal PDU activities beyond those prescribed at a national level. Sharing this progress in the public domain supports the current low carbon public verification undertaken by the author, with further commitment by the organisation through the announcement of its net zero carbon ambitions (HM Government, 2019i).

8.5 Action research feedback and reflection

The progression, development and implementation of the action research activities, has been a cycle of continuous improvement loops. The research aim, to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). Through the implementation and development of a WLCPT a suitable context for a shift in practice has been tested. As WLCPT has been embedded within the organisation and its supply chain, a chain of events has followed. This has largely been as a response to the data reported, the requirements of the organisation, and feedback from users on the process undertaken; their perceptions of low carbon and activities to influence the organisational culture, through the direct influence of the behaviours of people as part of the wider change management requirement. It is widely recognised that 'culture is a set of living relationships working towards a shared goal, it is not something you are, but something you do' (Coyle, 2018) and that the culture of an organisation is about the people within the organisation (Mayhew, 2016). This multi-layered complex approach affects the implementation of WLCPT and the ongoing business system and cultural change requirements, the survey and action research analysis both highlight the following key areas and are deemed to require ongoing focus, building upon the results from this study:

- leadership
    - where there is a relationship between organisational carbon leadership (VAR 4) and quality of training (VAR 5) with *p* 0.01. There is also a relationship between organisational carbon leadership (VAR 4) and organisational culture (VAR 6) with *p* 0.01;
- training
    - where there is a relationship between quality of training (VAR 5) and organisational culture (VAR 6) with *p* 0.01;
    - where there is no relationship between type of training (VAR 10) and tonne of carbon (VAR 8) with *p* 0.20;
- organisational change
    - where there is a relationship between organisational change (VAR 3) and quality of training (VAR 5) with *p* 0.01. There is also a relationship between organisational change (VAR 3) and organisational culture (VAR 6) with *p* 0.00;
    - where there is no relationship between there is a relationship between organisational change (VAR 3) and low carbon promotion (VAR 11);
- carbon versus cost reconciliation
    - where there is a relationship between cost (VAR 7) and low carbon prioritisation (VAR 2) with *p* 0.0;
    - where there is no relationship between cost (VAR 7) and tonne of carbon (VAR 8) *p* 0.2.

In addition to this the action research process has further highlighted the additional key areas:

- tools and systems development;
- carbon reduction embedded within 'business as usual' activities.

For leadership, this is not just in the context of the head of the organisation, but low carbon leadership of individuals empowered across the organisation and supply chain to contribute to a low carbon business and economy. Level of knowledge, type of training and learning approaches, alongside the implied success of how knowledge sharing is undertaken is an essential ongoing continued improvement activity, in order to change innovation into business as usual practices. Carbon versus cost is also linked to knowledge share but more widely that there is also a myth that needs to be challenged in that low carbon solutions can lead to reduced cost and improved efficiency. Understanding when these practices become minimum standards, and applied at the early stages of project level optioneering and scope development, rather than continually being viewed as innovation, also allows for further investment into research and development for new technologies and approaches. Recognising that these carbon innovations may not lead to reduced capital cost at the outset, is an area that has also been recognised and evidenced by Skanska (2019). Better understanding and influence of how assets should be maintained or improved to better maximise resources is required as a change from the current project focus. Continued improvement of carbon quantification and alignment to cost is required, this change from the current WLCPT and PCT to a combined Cost and Carbon Tool (CCT) is the next step for the organisation, aligning further to BIM and a wider digitalisation of systems and processes, through the internet of things. The organisations current review of carbon activities and commitments to next zero, has resulted in a greater resource commitment in this area, from assurance, reporting, leadership, training and the wider link to climate change mitigation and adaptation and greater alignment to United Nations Sustainable Development Goals within e:Mission 2030. Along with the change of focus for the Carbon Planning Manager role to that of supporting the development of carbon and cost alignment and linking to wider industry and academia.

In validating the authors' activities additional feedback was sought from key individuals across the organisation, supply chain and wider industry this was in the form of a survey requesting three key questions to be answered. A total of ten responses were received; question 1 was completed by nine respondents, question 2 was completed by eight and question 3 was completed by ten. The following sections provide further details for reflection, the full responses can be found in Appendix P. Sections 7.5.1 to 7.5.3 utilise direct '*quotes*' from the full returns.

8.5.1 Whether the implementation of (Eric) WLCPT has supported the prioritisation of low carbon in Flood Coastal Risk Management (FCRM)

In asking respondents whether the implementation of (Eric) WLCPT has supported the prioritisation of low carbon in FCRM, it was clearly articulated that its implementation has supported the organisation by helping '*people to think about alternative lower carbon solutions compared to what they had previously planned'*. The WLCPT has created the '*opportunity to make informed decisions, allowing our delivery teams to change the way we design, operate and maintain our assets, in a way that will reduce CO_2 emissions and save money'*. Through the *'mandatory use of the tool has ensured that carbon must be a discussion within every business case'*, supporting *'carbon conversations especially around targets and measures'* and *'helping to make carbon more tangible and more 'real' to people'*. As a data driven organisation WLCPT *'has helped to identify the challenges ahead - both in terms of emissions and low carbon ways of working'*, providing *'a single source of truth on whole life carbon'* which has helped move the business forward, not just within FCRM *'but also a wider impact across the organisation'*. It has also been recognised that the transformational change that WLCPT has provided *'has been a game changer with people able to articulate carbon as a practical element of a project rather than a theoretical assumption'*, with the *'ability to model various options at the early stages of a project has meant the planning conversations have been able to add value around carbon considerations before final decisions are made'*. WLCPT is recognised as being '*vital to enabling FCRM to measure its carbon emissions. It is recognised as an industry leading tool for this purpose'*.

In addition to this positive reinforcement that WLCPT has supported low carbon prioritisation, respondents and the author also recognise that this comes at a cost requiring *'an extra activity at a point in time often when the design decisions have been made so the opportunity to make a change has been lost'*. Within a CAS, transformational change must be supported by continued improvement and incremental change in order to sustain a long term and in-depth organisational culture change. The future need to integrate WLCPT *'capability into business activities to use the intelligence to change our decisions'* along with providing *'evidence to leadership that the carbon issue needs to be prioritised'*. This is being supported by a '*pilot study setting carbon as the critical success criteria for the business case and investment decision for the pilot projects, to allow us to understand better the ramifications of our choices'*, this should support the challenge which the tool does not fully do which is *'to think properly at the outset of a project what are all the potential options available to me to reduce* *the risk of flooding at X community'*, '*taking a catchment-based approach in FCRM and undertaking genuine options appraisal which properly considers no Carbon and low Carbon measures is needed'*. Allowing for future offset of '*un-avoided carbon'* building upon the *'business change programme'* that WLCPT has supported over the last five years, helping the organisation on its carbon maturity journey for PAS2080. Whilst the activities undertaken through the implementation of WLCPT have often been carried out as a planned or reactive response to improve current approaches or build knowledge and skills within the organisation, the action research activities have enabled the organisation, to provide some influence in prioritising low carbon in UK public sector FCRM construction, with future work building upon the foundation set by the implementation of WLCPT.

8.5.2 Whether the wider promotion of (Eric) WLCPT and supportive training has contributed to an organisational culture change in the Environment Agency (EA) and its supply chain in the context of carbon reduction in FCRM

The response to the contribution, WLCPT has achieved was tempered, with an understanding that the WLCPT provided a *'process and culture can't be changed by process alone'*. Although through the branding and marketing of WLCPT 'Eric' as a name and label the campaign had *'raised awareness and everyone knows who 'Eric' is and what it's for'*. Even '*well known in and beyond the FCRM community including the supply chain*' the influence was stronger within project teams rather than the wider FCRM departments.

Respondents and the author both recognise that the e:Misison 2015 -2020 plan does not fully align to current legislation which is now set at net zero carbon by 2050; the e:Mission 2030 plan will look to address these future requirements, further information can be found in Appendix Q. This has been echoed by a recent statement by EA chair:

> *The Environment Agency has today (10 October) set itself the aim of becoming a net zero organisation by 2030 – ensuring that its own activities and its supply chain are taking as much carbon out of the atmosphere as it is putting into it* (HM Government, 2019i).

Recognising that culture change '*needs to start at the top'*, the '*implementation and embedding of the new ways of working has taken a number of years'* and the activities undertaken as part of the action research study has supported and provided *'evidence that the carbon management process is starting to gain real traction'* with WLCPT (Eric) and its supportive training and documents still '*contributing to EA organisational culture change'*. It is widely recognised that WLCPT (Eric) is providing the *'basis of a culture-change that leadership and other drivers are now building on'*, but there *'is a long and challenging journey ahead but 'Eric' is providing us with the intelligence of where we are at and where we need to be. The training has encouraged staff and suppliers already working in a low carbon way to continue and is ensuring that people who are unfamiliar feel confident in broaching a new way of working'*. Further information can be found in Appendix K.

8.5.3 Whether author in the role of Carbon Planning Manager has successfully supported the prioritisation and promotion of low carbon in FCRM and wider industry.

This direct feedback on how the author has supported the action research activities and learning, has been noted as being '*instrumental in building the expertise, practices and tools we now have in the organisation'*, ensuring '*standards are industry leading and that as an organisation we have the evidence of our carbon performance against targets'*. The author has *'significantly raised the profile of carbon and the need to reduce our emissions in FCRM and influenced a growing ambition to become a net-zero carbon organisation in the future'*. As an action research approach public verification and author learning is key to the study practice, though knowledge sharing across industry (McNiff, 2011), low carbon approaches undertaken within the organisation, have been shared *'engaging both internally and externally'*, successfully *'improving knowledge within the EA and raising awareness of the work we have done to our supply chain and other associated groups'*, an example of which is via the Cross Whitehall Technical Group, *'which has greatly enhanced the Carbon understanding and knowledge within the wider industry'*. Although Complex Adaptive system (CAS) theory is in the context of the organisation and its supply chain in UK public sector FCRM construction; through the sharing of knowledge and data new building blocks and emergence of new 'agents' in the form of improved skills and awareness are happening within wider industry. Feedback has collaborated the view that without the authors' focus and ambition to improve low carbon across the organisation '*there would be no Eric'* as the *'architect of the tool and is an excellent advocate of how the tool should be used to identify low carbon opportunities and reduce the levels of carbon throughout the whole life cycle of an asset'*. The author is viewed as the *'acknowledged expert within the organisation'*. The activities undertaken by the author across industry as a '*regular speaker at industry events'*, and through the submission of WLCPT (Eric) and the author's direct work, '*have been short listed for a number of industry awards'*, and is recognised as *'one of few women leading a powerful change in culture and behaviour'*.

There is however, still further work to be undertaken for low carbon ways of working to truly be *'mainstream and embedded in our culture'*, the skills and expertise of one person is not the correct or chosen way forward. The opportunity through a net zero approach, the organisations future e:Mission 2030 plan; recognised and evidenced social change; the progress of a citizens assembly (HM Government, 2019j) and interest in climate change and GHG reduction, there will be renewed *'interest in this topic'*. The challenge of whether the organisation has sufficient resource has been recognised with the author's professional role. Reflecting on this further, it also recognises that influence and awareness has primarily been within the project management delivery team arena rather than as core to the day-to-day roles across the organisation. This in part is also a reflection of where the WLCPT is currently utilised and how carbon has been promoted and prioritised in line with e:Mission 2015-2020 and through construction activities.

8.6 Summary and link

The action research approach comprised of two main activities and focused on testing the following research objectives:

Action 1: implementation of a WLCPT and supportive training

- OB6: To investigate whether tonne of carbon influences cost;
- OB7: To investigate whether the quality of implementation of a whole life carbon planning tool influence tonne of carbon;
- OB8: To investigate whether type of training influences tonne of carbon.

Action 2: prioritisation, implementation and promotion of low carbon solution

- OB9: To investigate whether low carbon promotion influences organisational culture.

The level of low carbon prioritisation has improved within the organisation this is tested through the Capital Carbon Maturity Review (EA, 2019g) and its alignment to PAS 2080 (BSI,

2016) as a best practice guide to carbon management. The results infer that H6: The tonne of carbon does not influence cost, however the creation of factsheet and case studies to support low carbon and low cost findings within FCRM construction along with a carbon and cost correlation. The development of greater evidence outside of individual project results is required, whereby initial cost estimates and scope development do not bias the data. This is supported by the testing of H7: the level of quality of implementation of a WLCPT does not influence tonne of carbon, whereby the largest tonne carbon increases were achieved by project teams who did not completed the WLCPT processes from reporting, recording and informing low carbon decisions on projects. H8: the type of training does not influence tonne of carbon, supports these findings whereby projects that had higher levels of training also had lower levels of tonne of carbon. Collectively these hypotheses are representatives of H9: the level of low carbon promotion influences organisational culture, it is recognised that organisational change and low carbon promotion are iterative activities that influence each other dependant on the activities and changes undertaken.

Chapter 9 will look to conclude the findings and discussions of the study.

CHAPTER 9: FINDINGS AND DISCUSSION

9.1 Introduction

For many action research approaches the context of the study is usually the organisation, often linked to a change agenda in order to create greater skills and knowledge about a particular organisational issue, with the aim of improving the situation (Emerald, 2019). Chapter 6 and 7 presented the analysis from the survey and action research activities, including feedback received from key individuals. The author has looked to continually improve their individual learning along-side the processes and tools implemented; whilst challenging perceptions, influencing individuals and groups, through knowledge share and awareness raising. Over the duration of this study, the true test has been, whether the prioritisation of low carbon solutions influences organisational culture, in UK public sector FCRM construction and whether WLCPT have contributed to the culture change within the organisation, its supply chain and externally within the public domain. This chapter covers the conclusions of the study via, awareness of a problem, the 'improvement research', highlighting the problem solving and performance improving nature of actions 1 and 2 and the feedback received in relation to these.

This chapter is structured as follows:

- awareness of the problem;
- improvement research:
    - what the survey results mean for UK public sector FCRM construction;
    - problem solving and performance improving Activity 1;
    - problem solving and performance improving Activity 2;
    - gaps in research;
- building action research knowledge and complexity theory;
- the significance of the research for the author;
- the significance of the writing-up the research;
- the significance to the authors' workplace context;
- summary and link.

9.2 Awareness of the problem

Current planetary CO_2 effects is not new science (Wogan, 2013, The Guardian, 2005) but the acceptance of the effects and the need to change has been unrealised as society continues to downplay the science behind the facts (Time, 2018). The lack of awareness and sense of urgency that the UN has presented (UN IPCC, 2018) has not been understood, accepted or felt by many. It is this latter challenge which has resulted in little progress in reducing carbon within everyday activities; such large scale and significant cultural changes cannot be undertaken in a customary way, particularly in political organisations that have conflicting priorities and drivers (Vermaak, 2013, Weick et al., 1996, Letiche et al., 2005, Catrien et al., 2017). Keast and Brown (2006) state that despite the impatience to see in-depth change it cannot happen overnight; from a societal and organisational perspective this drives conflict whereby the evidence of change and improvement are not necessarily in line with the organisational priorities or culture. This research has studied the current practice of UK public sector FCRM construction; it has developed knowledge about existing realities and perceptions in prioritising low carbon through the implementation of WLCPT and the wider promotion, prioritisation and implementation of low carbon solutions. It is widely accepted that implementing low carbon solutions have additional advantages in regards to cost and efficiency (HM Treasury, 2013), but in order for low carbon initiatives to be sustained, good carbon management processes need to be implemented as part of wider organisational change (BSI, 2016).

9.3 Improvement research

These research findings will be covered in the following order:

- conceptual framework;
- key concepts;
- what the survey results mean for UK public sector FCRM construction;
- improvement research
- problem solving and performance improving action 1;
- problem solving and performance improving action 2;
- gaps in research;
- recommendations for the future.

9.3.1 Conceptual framework

The organisational line of sight from corporate strategy to WLCPT, form the building blocks of the CAS, through the loop of feedback and reflection, testing the hypotheses ('rules' in CAS) these are tested for strength, whereby weak rules are replaced by strong rules. All of the hypotheses have been tested and with the majority found to be true however, as the WLCPT has developed and the feedback loops of reflection have progressed the availability of data for analysis through the improvements in training and wider low carbon promotion the hypotheses have been strengthened through a continued improvement approach. As each change in requirement is made at the lower level it is done so in support and reinforcement of the rules and CAS in which it resides (Holland, 2014).

9.3.2 Key concepts

Reflecting back on the key concepts identified at the start of the study as detailed in section 3.5, section 5.3 and Appendix A. Three key concepts were identified of which the objectives were aligned. Key concept 1 - role of UK public sector FCRM clients in success of reducing carbon and cost within construction and where teams are empowered to make decisions, raised the following question: 1) what is the current status on carbon within UK public sector FCRM construction and what role does the organisation play? Answered by OB1. Whether demography of professionals influences low carbon prioritisation, plays a role in ensuring that for UK public sector FCRM construction the client plays a pivotal role in requiring low carbon solutions. The improvement in skills and capabilities within the public sector over the duration of this study has resulted in a progression in low carbon prioritisation and alignment to best practice approaches as identified in ICR (HM Treasury, 2013) and PAS 2080 (BSI, 2016).

Key concept 2 - increased climate change challenges and need for greater action across industry, raised the following questions: 2) can low carbon initiatives (including tools) influence the organisation and wider construction industry? Answered by OB2, OB3 and OB4. 3) what can people do to mitigate climate change to protect the planet for future generations, within a work environment? Answered by OB5. Whether organisational culture and leadership influence low carbon prioritisation; a change and continuous improvement approach has resulted in low carbon being better prioritised within the organisation and its supply chain, by a change in the organisation culture through the incorporation of new tools, processes and systems an iterative and positive affect has been achieved, and embedded to achieve a sustainable change.

Key concept 3 - need for greater action to reduce carbon across wider construction industry, raised the following question: 4) costs are driving project decisions; how can project teams within FCRM construction reduce carbon? Answered by OB6, OB7, OB8 and OB9. Whether the quality of implementation of a WLCPT influences cost, has been evidenced by the cost, carbon and efficiency correlation and the availability of case studies and factsheets, this process of evidencing good practice is an ongoing and iterative process, whereby business and usual low carbon approaches, must be replaced by more innovative low carbon solutions, which need to be market driven to generate a more competitive cost comparison compared to traditional approaches. Through the prioritisation of low carbon within the wider industry, change in organisational culture and strong and visible leadership an emergent market can be encouraged.

Through the greater visibility of the tonne of carbon in relation to cost and the influence one has on another, a wider understanding of how both cost and carbon can be reduced and affected by decisions made during the project lifecycle. The building up of evidence and reporting of progress has resulted in improvements to EA five case business template the governments guide to public sector projects, through the evidencing of carbon and wider sustainability requirements as part of the business case approval. How the type of training influences both low carbon prioritisation and tonne of carbon, has been significantly improved through the implementation of WLCPT a repeatable and consistent quantification process for use at all stages of the project lifecycle. The change from a capital to a whole life cradle to grave WLCPT, that is aligned to PAS 2080 (BSI, 2016) and RICS method of embodied carbon (RICS, 2012), takes forward current best practice approaches, supporting the wider industry.

Through the answering of OB2 and OB9, whether organisational change influences low carbon prioritisation and whether, low carbon promotion influences organisational culture. Both of these objectives have variables that present interchangeable improvement, for example by influencing organisational culture low carbon prioritisation is improved (OB2) and vice versa, the same also occurs with OB9. Through the implementation of this study the low carbon promotion activities have also influence wider industry with organisations viewed as a key public sector leader in regards to carbon reduction and having the evidence to support this (tools, training and case studies). Through a change in the organisations' in its alignment to

PAS 2080 (BSI, 2016), embedding of a WLCPT along with the culmination of publicly announcing a net zero commitment by 2030. Visible leadership has been presented through evidence directly from this study alongside the strong leadership demonstrated by the EA. The activity of public validation, wider promotion of low carbon and sharing of practical evidence and WLCPT has led to wider industry being influenced, this is seen through the utilisation of the WLCPT by 322 external users (as of September 2020).

9.3.3 What the survey results mean for UK public sector FCRM construction

The main survey results have been analyses and the hypotheses tested:

- H1: the demography of participant has little or no influence on low carbon prioritisation;
- H2: the level of organisational change does influences low carbon prioritisation;
- H3: the level of organisational carbon leadership does not influence on low carbon prioritisation;
- H4: the quality of training does influence on low carbon prioritisation;
- H5: the level of organisational culture does influences low carbon prioritisation.

The survey results provided a baseline of the current position of UK public sector FCRM construction, although some of the results were in line with literature findings others were not and offered the opportunity for further research. Low carbon prioritisation is not focused on one specific demographic within the survey results indicating that there is little relationship between demography of professionals and low carbon prioritisation. Indicating overall a positive response on how organisations implement, promote and prioritise low carbon initiatives; however, low carbon planning and carbon calculation were not consistently discussed at each project stage, indicating that industry recommendations via the ICR (HM Treasury, 2013) were not being carried out.

The level of change did have an influence on low carbon prioritisation, but required development areas and the latest industry recommendations being put in place. Building upon this evidence where carbon information is monitored within the public sector and contributes to targets for organisations. The overall support for low carbon solutions being the same or lower than cost can be built upon as the current monitoring and reporting elements were not as effective as they could be, with the likely outcome that low cost is prioritised over low carbon solutions, resulting in low carbon targets being missed.

PAS 2080 (BSI, 2016) states ‘Leadership’ as a key requirement however, the high level of participant stating ‘I don’t know’ indicated that the visibility of who leads is not consistent or visible. This demonstrated a lack of clarity on the leadership of low carbon initiatives, calling into question the respondents’ view of prioritisation, implementation and promotion of low carbon which was not reflected within the literature with a low level of available examples for FCRM. This was supported by results demonstrating public sector respondents less focused on low carbon planning and calculation and less motivated on promoting and prioritising compared to the private sector. Further clarity on who is leading; what is required and how carbon data should be used, supported by improved training was identified as a key improvement area.

The quality of training did have an influence on low carbon prioritisation, but with satisfaction levels not reflecting good practice, as per the ICR (HM Treasury, 2013) and PAS 2080 (BSI, 2016), in regards to low carbon being planned for and calculated in the early stages of a project lifecycle in order to gain the greatest savings.

The level of organisational culture does influence low carbon prioritisation, however with the development areas required around organisational change, clarity on leadership and lack of alignment to low carbon best practice, the survey results presented a culture that is now being supported and developed to adequately and robustly influence low carbon prioritisation.

9.3.4 Problem solving and performance improving Action 1

Action 1 results have been analysed and the hypothesis tested:

- H6: the tonne of carbon does not influence cost;
- H7: the level of quality of implementation of a whole life carbon planning tool (WLCPT) does not influence tonne of carbon;
- H8: the type of training does not influence tonne of carbon.

Through the implementation of WLCPT and supporting documents, the maturity of the organisation has improved and alignment to industry best practice has created a cycle where by improvements to processes, and supportive training, influences the implementation of low carbon solutions. Which in turn influences organisational culture and the perception that low carbon can lead to reduced cost. As additional data is provided from the completion of WLCPT and case studies created, further evidence is provided for training aids, which in turn influences improvements to process and the implementation of low carbon solutions. The results from H6, infer that tonne of carbon does not influence cost, the results analysed utilised data at the start of the project with the approved budget and CMT output, this was compared with the end of project carbon and cost outputs. The analysis has identified that cost allocation is not always provided based on the project estimate but a nominal budget of £100,000. This data, is not a formal estimate compared to the carbon estimate and therefore creates a bias as to whether the analysis is unduly influenced by the need to provide more robust cost estimates at project inception. This area of work has been identified as part of the improvement process and greater alignment of cost and carbon.

The quality of implementation of a WLCPT does not influence tonne of carbon, this is also an area that requires further focus in terms of governance and compliance in submitting contractual data. This is an improvement area for both public and private organisations. The provision and ease of capturing carbon data, has been tested through the course of this study. Through the management of an asset or delivery of a project, key users from client, designer, constructor, cost manager or stakeholder as examples, are required to undertake specific activities at various stages. These activities are often repetitive although the outputs may vary within the WLCPT, key processes are required to be followed to systematically estimate the level of carbon usage, through to a bottom up granular build-up of carbon usage aligned to PAS 2080 (BSI, 2016) and RICS methodology embodied carbon (RICS, 2012), this cradle to grave approach is aimed at providing the users information on carbon hotspots to aid informed carbon related decisions. Being Excel based, it requires manual population of data; completion of the tool is currently not supported by data from source, this in itself requires a greater level of assurance and governance to ensure that reported data is accurately reflective of the project commitments and is undertaken when required. This drawback cannot be resolved within the existing WLCPT, recognising its limitations and the next stage changes required, has resulted in the requirements for an integrated carbon and cost software system. This will allow for future estimating of carbon and cost to be undertaken at set stages, with specific rules applied to the carbon or cost output, supporting future improvements to framework and contractual commitments.

The influence on type of training and low carbon prioritisation, has been through the creation and implementation of WLCPT and its functionality. However, due to the challenges with leadership and wider governance, the relationship between process, perception and people has not been fully resolved through this research study. Evidence for the type of training solutions provide a clear base that tonne of carbon influences cost. However, due to the inconsistency in the completion of training identified and implementation and development of WLCPT further availability of data and widening of available population or industry sector research is required in this area. This in turn is also evident for H7 and the quality of implementation of a tool, the nature of the WLCPT has caused wider challenges beyond the scope of this action research study which have influenced the level of successful implementation. These gaps in research will be discussed further in Section 9.3.6. The type of training implemented factors into the level of success, the functional requirements to complete WLCPT and low carbon workshops supported by case studies and factsheets have an ongoing influence, no one training solution provides all of the evidence.

9.3.5 Problem solving and performance improving action 2

Action 2 results have been analysed and the hypothesis tested:

- H9: the level of low carbon promotion does influence organisational culture

Through the direct role of the author the level of organisational culture has been influenced. This has been through the wider promotion, prioritisation and implementation of low carbon solutions. Evidence via the Capital Carbon Maturity Review (EA, 2019g), highlights the changes realised in line with PAS 2080 (BSI, 2016) and other emerging industry best practice, with key improvements made in the following areas:

- leadership and governance;
    - improvements to roles and responsibilities;
    - improvements to governance structure;
    - availability of ongoing training support;
    - greater oversight of carbon reduction performance and feedback to drive continuous improvement;
- target setting/baselines/monitoring
    - establishment of carbon baselines via WLCPT and continued development in this area;
    - improvements to organisational carbon targets;
    - monitoring and reporting against targets and baselines at project; programme and organisational level;
- carbon reduction hierarchy;
    - ability to identify carbon hotspots and opportunities for further reduction;
    - further alignment to carbon reduction hierarchy;
- quantification;
    - utilisation and improvement to carbon data sources and alignment to PAS 2080 (BSI, 2016);
    - refinement of whole life quantification from capital and operational to the inclusion of sequestration;
    - progressing of cost and carbon alignment;
- reporting;
    - defining, developing and communicating reporting across the organisation and supply chain.

Each of these continued improvement areas, have been supported by the wider external promotion of WLCPT and the carbon leadership of the organisation across industry. This has resulted in the author, regularly attending, supporting and presenting at industry events (Appendix I). In addition to this the WLCPT is utilised by 322 external users (as of September 2020).

Seeking further feedback from the organisation, its supply chain and external partners, author has looked to further validate that the actions implemented have: influenced low carbon prioritisation; influenced the culture of the organisation and validated the role the author has played in this specific change, further details can be found in sections 8.5.1, 8.5.2, 8.5.3 and Appendix L. This feedback picks up on the method of implementation and the way it has looked to address process, people and perceptions, through the implementation of WLCPT (process)' wider promotion and prioritisation of low carbon (people) and providing evidence for knowledge share to challenge perceptions in regards to low carbon and the correlation between carbon, cost and efficiency (perceptions). This research study has provided a foundation for future improvement and a basis on which the organisation has been able to take the next step towards a net zero carbon ambition.

9.3.6 Gaps in research

This action research study has focused on UK public sector FCRM construction, in doing so it has given rise to gaps within the research which has resulted in wider success of low carbon being challenged. Through the implementation of WLCPT within a leading government organisation, its supply chain and wider industry, the organisation implementation has been within a specific delivery department. The ongoing challenges of implementation across the organisation has been restricted due to organisational focus at the outset of this study. With the WLCPT and carbon calculation only being a mandatory requirement within the WEM framework and not the Minor Works or MEICA frameworks. This has caused disconnect and a level of confusion across the organisation diluting the level of prioritisation and requirement across the wider organisation. In addition to this the consistent level of leadership from the Chief Executive down to the author in prioritising low carbon has also been a challenge resulting in inconsistent completion of WLCPT by the delivery department and the supply chain; recognising that type of training and awareness have been addressed within this study, future improvements to governance have been proposed, but the direct project and contract management governance and compliance has been outside of this research scope.

Whether cost influences tonne of carbon is unintentionally affected due to the initial cost estimates not corresponding with the initial carbon estimates. This along with provisional cost budgets being allocated to projects rather than informed estimated costs, creates, ambiguity in the data whereby only the actual final cost and carbon can be truly reviewed and tested as to whether cost influences carbon. The initial cost estimate accuracy is outside of the scope of this research.

The quality of implementation of a WLCPT, has been inadvertently affected due to the tool solution being based within Excel and the level of IT systems within the organisation and its supply chain. The level of digitalisation, available within the current WLCPT has resulted in the need for manual completion, causing technical challenges in regards to utilisation of source data and better integration of BIM as part of the wider solution, these changes have been facilitated by the current approach and are covered further in Section 8.5.

In addition to the process aspect, the people and perception requirements have been focused solely on the project team and wider industry in regards to the availability of evidence and utilisation of the WLCPT. This research has not expanded on the behavioural change of individuals or teams, which the author recognised would have had a direct impact on the level of success of the research study.

9.4 Building action research knowledge and complexity theory

This research has had the opportunity to observe and track the success levels of the implementation of WLCPT, and its effect on organisational change in prioritising low carbon in UK public sector FCRM construction. Existing knowledge and theory base, in regards to complexity theory and complex adaptive systems (CAS) and how the prioritisation of low carbon in practice can lead to a wider organisational culture change. The author has looked to derive a theory from data, systematically gathered and analysed through the research process (Bryman, 2008). This systematic and unbiased view, with its real-life context using multiple sources of evidence (Yin, 2009), including feedback from the organisation, supply chain and industry representatives on its level of success has generated an emerging body of knowledge to support CAS theory and practice. Whereby an account of the descriptions of the research (what was done) and explanations (why it was done and what was aimed for) has been undertaken and recorded (McNiff, 2011).

In determining that the prioritisation of low carbon in UK public sector FCRM construction can lead to organisational culture change, this has been publicly scrutinised through the incremental activities undertaken through the implementation of WLCPT and supportive training and documentation. This includes the PAS 2080 (BSI, 2016) specification, through loops of continuous improvement activities the capital carbon maturity of the organisation has been tested, and further validated through feedback. The prioritisation, implementation and promotion of low carbon solutions, is required in order to sustain the change to an organisation's way of working. This is supported by existing CAS, complexity theory; the speed, depth and size of implemented changes, is also dependent upon the continued 'active entity' (Hughes, 2019), in order to ensure that low carbon is deemed an essential part of every day decision making.

The utilisation of loops of continuous improvement in the context of CAS and author activities, transformational change can be achieved (Brown, 1997, Weick, 1999, Phelps and Hase, 2002) but must be undertaken in line with emergent industry practices, greater understanding of the system and the consistent and repetitive approaches required; along with wider knowledge sharing across industry, through an open source approach and a common method of carbon data quantification. According to Holland (2014) a CAS should be described as follows: 'An easy way to accomplish this objective is to make the framework computationally universal, so that any model that can be simulated can be described within the framework. In practice, this means setting up a generated system wherein the operators amount to the basic 'machine level' instructions of a general-purpose computer'. The functionality of the WLCPT although perhaps a crude form being Excel based, provides this framework as does the repetitive steps to complete the practice. It is the dynamics that surround the WLCPT as a CAS that require the changes to organisational culture, low carbon prioritisation, type of training and carbon leadership. To achieve this, successive steps in generating the change must correspond to iterative variation in the structure of the organisation, its culture. The users in the context of this study those operating within UK public sector FCRM construction to facilitate adaptation and evolution (Holland, 2014). The role of the author has instigated and enabled this system, organisational and industry change, which through continued development and maturing of processes and practices will enable a shift to a net zero future.

9.5 The significance of the research for the author

Through the development and undertaking of this action research study the research aim, to investigate the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). The implementation and development of a WLCPT a suitable context for a shift in paradigm has been tested and achieved. This has been important in author's professional career development, having the ability to focus on authors values and examine low carbon within UK public sector FCRM construction. Through this study author has revealed the nature of these values as the living standards of judgement used in making sense of the work required. Changes to approaches needed and the ongoing professional development in the subject of low carbon. The reflective nature of action research has required the constant consideration of ‘What am I doing here?’ and ‘How can I improve?’ The process is ongoing and is a reflection of the author’s personal and professional life.

This action research approach has continually required evidencing of low carbon solutions and it’s embedding within the organisation, this ongoing account of action and evaluation of success author has either undertaken directly or via an independent source has been done to continually improve a situation. Each change has contributed to the development of author’s professional competence and sense of professional well-being. Providing the opportunity to demonstrate my developing low carbon values, practice and knowledge. Through writing this action research study, the author is developing a research-based professionalism in low carbon.

Through the development of this study author has learnt a great deal about their personal approach to change implementation and how processes and systems must be made easy and integrated to sustain long term improvement. Prior to this action research project author deemed that the corporate values of the organisation should be enough to ensure that the right low carbon decisions should be undertaken. However, the competing priorities and demanding requirements on individuals coupled with those values and priorities of individuals in a leadership position can heavily influence whether low carbon activities are realised and deemed as a necessity. The challenges of perceived and actual barriers and the necessary time and space for individuals and teams to work through and challenge these behaviours and processes is a necessity to support project teams in making the right choices, should be made alongside the change in process and perception around low carbon.

As a researcher in a challenging subject area and a significant organisational change, development of personal resilience and making time to celebrate authors’ strengths and to work on their weaknesses has been invaluable to this process. The perceived level of success of WLCPT within the organisation in comparison to the external value it has achieved, has raised the authors awareness continually remember that low carbon prioritisation, promotion and implementation has been an emerging area within industry and that author approach should be evidence based, with knowledge sharing opportunities undertaken as much as possible.

9.6 The significance of writing-up the research

In writing up this thesis the amount that has been achieved over the six-year period and the scale of the change required and the foundation it has provided for the organisation to progress to a net zero carbon ambition has been both significant and transformational. Through developing action research activities supporting complexity theory and CAS, the author has moved beyond depending on the theories of others, to providing theory and evidence on how the prioritisation of low carbon can influence organisational culture. Through this study author has been able to stop and reflect, question and explore alternative approaches, take stock of achievements and weaknesses, whilst continually working on ways of improving the implementation of WLCPT and the wider prioritisation of low carbon solutions in a coherent and systematic way.

9.7 The significance to the authors' workplace context

Through the receipt of feedback author has confirmed that the action research study has been '*instrumental in building the expertise, practices and tools'*, ensuring *'standards are industry leading', 'significantly raised the profile of carbon and the need to reduce our emissions in FCRM and influenced a growing ambition to become a net-zero carbon organisation in the future'*. Public verification as part of the wider industry sharing, *'has greatly enhanced the Carbon understanding and knowledge within the wider industry'* and is viewed as *'acknowledged expert within the organisation'*. The authors participation as a *'regular speaker at industry events'*, is recognised as *'one of few women leading a powerful change in culture and behaviour'*, further details of responses can be found in Appendix K.

9.8 Summary and link

Chapter 9, provided the study findings, form awareness of the problem through to improvement research, linking back to the initial conceptual framework and key concepts. The findings from the survey and action research have been provided along with gaps in the research, and building of action research knowledge and supporting complexity theory, CAS. The significance of the research from the author and organisational context has also been provided.

Chapter 10 will cover the conclusions of the study and the future recommendations.

CHAPTER 10: CONCLUSIONS AND RECOMMENDATIONS

10.1 Introduction

Chapter 9 provided the findings and discussion for this study; Chapter 10 provides the conclusions and final recommendation.

10.2 Conclusions

Climate change is a known and recognised across the global community. The science behind the identification and quantification of GHG is understood with CO_2 being a known indicator and factor for change. Within UK Government, *The Climate Change Act 2008* (HM Government, 2019g) sets out the ambition, and at industry level, climate emergency and net zero commitments have been made, along with the lead government organisation who is the main focus of this study. The EA has committed to net zero by 2030 and to investigate delivery of absolute zero by 2050 (HM Government, 2019i). The study has investigated whether the prioritisation of low carbon solutions influences organisational culture, in the context of UK public sector FCRM Construction. Through the implementation and development of a WLCPT a suitable context for a shift in practice has been tested.

Through answering the following research objectives, the research aim has been achieved:

- OB1: to investigate whether demography of professionals influences low carbon prioritisation;
- OB2: to investigate whether organisational change influences low carbon prioritisation;
- OB3: to investigate whether organisational carbon leadership influences low carbon prioritisation;
- OB4: to investigate whether quality of training influences low carbon prioritisation;
- OB5: to investigate whether organisational culture influences low carbon prioritisation;
- OB6: to investigate whether tonne of carbon influences cost;
- OB7: to investigate whether the quality of implementation of a whole life carbon planning tool influences tonne of carbon;
- OB8: to investigate whether type of training influences tonne of carbon;
- OB9: to investigate whether low carbon promotion influences organisational culture.

This thesis reflects the changing nature of implementing low carbon solutions within UK public sector FCRM construction and the role the author has played in its development. It offers an understanding of challenges in implementing new systems and processes within an organisation and its supply chain and is directly related to the wider learning across industry. It shows how the author has worked within a leading government organisation, to improve the area of low carbon within UK public sector FCRM construction. Making a claim to knowledge because with the evidence provided and the reprioritisation of carbon reduction within the organisation and through the implementation of a WLCPT; the establishment of the Carbon Planning Manager role, the author can show an improvement to their work. With evidence of reported WLCPT reported data, via case studies, factsheets and independently verified reviews of the WLCPT, reflecting on the strengths and challenges of low carbon within UK public sector FCRM construction. The processes of thinking, acting and making sense of the author's work, the narration of the processes and the changes that have taken place in the author's actions, show how low carbon knowledge can support a CAS providing practical evidence to support complexity theory; utilising a continued improvement loop of positive and negative feedback that is always being reformulated, reworked and continually improved upon, in order to achieve the aim of the study.

This thesis tells the story of how the author came to understand more fully low carbon and climate change values and explains organisation culture development and change as the author accounts for their role and their work. To carry out a research study that is directly part of the author's day to day profession and about an issue that concerns the author, has been a positive experience and challenging learning opportunity. This particular action research has contributed to both the leading government organisation, its supply chain and wider industry, providing a basis for future development and progress towards net zero carbon ambitions.

10.3 OB1: to investigate whether demography of professionals influences low carbon prioritisation

In conclusion the testing of H1: the demography of professionals influences low carbon prioritisation, results infer, null hypotheses cannot be rejected, there is no relationship between demography of professionals and low carbon prioritisation. Although there is a need for strong client leadership and promotion of low carbon, it is recognised that the low correlation offers the opportunity for all project team members to influence low carbon prioritisation, regardless of their role within a team or organisation. This is in support of the PAS 2080 (BSI, 2016) carbon management specification. In order to expand on this, further research is required to better identify which roles can influence carbon reduction and when, to better focus the actions individuals should take throughout the project life cycle.

10.4 OB2: to investigate whether organisational change influences low carbon prioritisation

In conclusion the testing of H2, results infer, reject the null hypotheses, there is a relationship between organisational change and low carbon prioritisation. Although a low correlation when baselined at survey stage, the evidence provided through the action research activities and the Capital Carbon Maturity review (EA, 2019g), provides the evidence that changes instigated through the implementation of a WLCPT, training, reporting, leadership, communications and promotion, can have a positive effect on the prioritisation levels within an organisation and its supply chain. However, it is recognised that these activities need to be continually developed and improved in order to achieve the new and future ambitions of net zero, implemented by the EA. In order to expand on this, further research is required to better identify the individual and team behavioural changes and how this can be supported to aid a better organisational change transition to net zero.

10.5 OB3: to investigate whether organisational carbon leadership influences low carbon prioritisation

In conclusion the testing of H3, results infer, null hypotheses cannot be rejected, there is no relationship between organisational change and low carbon prioritisation. At survey stage there was uncertainty on who led on low carbon; through the action research activities and creation of Carbon Planning Manager role, this has been strengthened. The evidence provided through the Capital Carbon Maturity review, provides the level of progress in this area along with more consistent and visible carbon leadership throughout the organisation. This approach aligns to PAS 2080 (BSI, 2016) principles and evidence from the ICR (HM Treasury, 2013), whereby strong organisational carbon leadership creates the system for empowering organisations and their staff to achieve challenging and ambitious targets. This is evidenced through the study by the organisation announcing a net zero ambition and by the substantiation of collaborative teams taking ownership of their carbon usage and targets, to make specific reductions on their projects and programmes, such as the example of PDU 6.

10.6 OB4: to investigate whether quality of training influences low carbon prioritisation

In conclusion the testing of H4, results infer, reject the null hypotheses, there is a relationship between quality of training and low carbon prioritisation; the analysis of the survey identified the need for further review of this as the link between satisfaction levels for training and utilisation of carbon data to prioritise/inform project options were not aligned or consistent with existing best practice approaches for carbon planning and calculation undertaken at options appraisal. Training and skills development are required for schools, colleges and universities along with current practitioners amongst clients and their supply chains, to ensure that individuals involved in project delivery are able to implement low carbon solutions.

10.7 OB5: to investigate whether organisational culture influences low carbon prioritisation

In conclusion the testing of H5, results infer, reject the null hypotheses, there is a relationship between organisational culture and low carbon prioritisation. Through the action research activities of implementing a WLCPT, the governance and wider communication along with the Capital Carbon Maturity review (EA, 2019g), and wider promotion of low carbon, provides the evidence that organisational culture can have a positive effect on the prioritisation levels within an organisation and its supply chain. However, it is recognised that both organisational culture and low carbon prioritisation are interlinked; by promoting one the other is affected and vice versa. The continued progress of these independently and collectively is required to continually improve and focus on the future net zero ambition.

10.8 OB6: to investigate whether tonne of carbon influences cost

In conclusion the testing of H6, results infer, null hypotheses cannot be rejected, there is no relationship between tonne of carbon and cost; however the evidence created through the action research activities challenges this result and through case studies and factsheets and carbon, cost and efficiency correlation data, qualitatively it can be confirmed that the tonne of carbon influences cost which this aligns with ICR (HM Treasury, 2013). Through this study additional data has been created and made available for the organisation, its supply chain and wider industry, bridging a gap within the literature available. The survey recognised that cost was prioritised at all levels of the project life cycle, whereas carbon calculation and planning was not. Through the implementation of the WLCPT and its supporting activities of case studies and factsheets and the cost, carbon and efficiency correlation, has better evidenced this for UK public sector FCRM construction. In order to expand on this, further research is required to better identify the influence of initial cost estimates and the early alignment to tonne of carbon. The incentivisation techniques should be available within contracts to ensure that that there is both a financial incentive rather than only a quality commitment to reduce carbon. Another identified research area is to better identify more granular correlation between carbon and cost, at both an asset level and below. Part of this work will be incorporated into the Cost and Carbon Tool (CCT) system which will replace (Eric) WLCPT in the long term. Outside of this tool, additional works are required on the difference between business as usual best practice approaches to carbon and its alignment to cost, and the more innovative low carbon approaches which are as yet untested or identified.

10.9 OB7: to investigate whether the quality of implementation of a whole life carbon planning tool influence tonne of carbon.

In conclusion the testing of H7, results infer, null hypotheses cannot be rejected, there is no relationship between quality of implementation of a WLCPT and tonne of carbon. Evidence analysed through action research activities, supports these findings. However it is recognised that through the repeatable and consistent application of a system the identification of carbon hotspots and challenges can be identified enabling a project team to make proactive interventions, as identified in the carbon optimisation and final carbon reports. However, it is recognised that a limitation of this study is the utilisation of an Excel tool rather than a software system. This aids data from source, improved assurance and alignment to cost data, the implementation of CCT will further help overcome the barriers identified within this study. What has not been included within this study is the sensitivity of the correlation between capital and operational carbon; the data is available within the WLCPT but has not been included as part of this study. In order to expand on this, further research is required in the following areas: ‘How digitalisation and improvements to information technology and data from source can aid implementation of low carbon solutions in construction’ and ‘How to better identify the correlation to the choices made as part of the capital solution and the effect on the operational outputs, the impact of tonnes of carbon and associated cost capital and operational cost’. The implementation of CCT will better facilitate the availability and correlation of this data for future statistical and trend analysis and will be incorporated within the author s’ role.

10.10 OB8: to investigate whether type of training influences tonne of carbon

In conclusion the testing of H8, results infer, null hypotheses cannot be rejected, there is no relationship between type of training and tonne of carbon. Through the implementation of WLCPT (Eric) e-learning, case studies and factsheets utilised as part of the low carbon solutions workshops. The two areas of carbon reporting and decision making are supported.by quantification, method and data through the WLCPT and making the low carbon decisions in line with identified best practice. This area of weakness was identified within the survey as lack of alignment to industry best practice. The implementation of a WLCPT facilitated a repeatable and consistent approach to quantification and data reporting and the availability of knowledge share best practice approaches has provided a new system change. In order to continue this awareness raising and improved skills and capabilities, the continuation of knowledge share through new case studies and factsheets should be incorporated into contract requirements and the undertaking project level carbon workshops should be part of the project process. However, it is recognised that the data reported via the WLCPT and the the inconsistencies in data is influenced by H7. Changing business as usual approaches to low carbon innovation is the next step in the evolution of this area, alongside the continued training of new starters within the organisation and supply chain. Reinforcement of management, governance and compliance for both public and private sector staff in the prompt and contractual commitment to providing good data.

10.11 OB9: to investigate whether low carbon promotion influences organisational culture.

In conclusion the testing of H9, confirms that the level of low carbon promotion influences organisational culture, this is evidenced through the action research activities and the Capital Carbon Maturity review (EA, 2019g). Alongside the wider promotion undertaken by the author in the role of Carbon Planning Manager, it is recognised that low carbon promotion can have a positive effect on the organisational culture and wider industry can be achieved. However, it is recognised that these activities need to be continually developed and are not solely due to this study. The effect of societal change at this particular point in time is not reviewed within this study and could be a new area of research. What is recognised and evidenced through this study is that the level of ambition and change required to achieve net zero is able in part due to the foundation that the work undertaken within this study has facilitated.

10.12 Thesis limitations

Throughout this action research approach what I know and how I come to know it has influenced what I have done. Putting this into practice, as a research practitioner I have taken this knowledge and looked to influence how other people act, this has been done by influencing what they know, through the implementation of a WLCPT, and its associated training, guidance and communications. The effect on how they think has been shaped through systems and process, intertwining carbon requirements into contracts, guidance, business cases and aligning to cost. What people see as important (their values) has been driven through leadership and communications, aligning the conceptual framework to the principles and requirements of the organisation. Influencing the culture of the organisation through people, process and perception, understanding the change requirements and how people respond to change, by supporting improvements to skills and capability.

However, despite this progress a key limitation of this thesis falls into three key areas, people – behaviours; process – separate cost and carbon systems and perception – it is everyone's role. In addressing people, it is recognised that a clearer behavioural insight review earlier in the process would have better shaped the rollout and implementation process, addressing the known barriers earlier in the research cycle. Although the research spiral has been used, throughout and looked to address challenges with practical action and reflections of what has work and what has not, a fundamental barrier has been behavioural, with challenges in overall governance, following existing processes and wider management of projects and contracts. This has impacted the ability to better embed the WLCPT requirement and gather in a larger number of data returns.

The process of implementing a WLCPT that is both manual (Excel) and only aligned to cost at asset level, was seen as a key limitation in the research; however, this drawback has been used to its best advantage through the raising of awareness, building of wider carbon management understanding and the logical steps required to quantify carbon. Constructing a better understanding of where carbon usage occurs and how to influence it. The limitation comes in where WLCPT is actively used and the need to improve automation of data and remove manual entering of information and this drives additional assurance and quality challenges, this research recognises and has supported, carbon and cost alignment into a more automated and one system approach. In addition to this the starting position for cost and carbon comes from two separate points, with cost allocated as an initial budget not based upon any explicit quantification but an approval limit. Whereas carbon is based upon a clear methodology and utilisation of high level data, this results in the full alignment of cost and carbon being biased in its results, as cost will always go up based on nominal approval limit rather than an estimated cost, the implementation of a combined cost and carbon tool (CCT) specifically looks to improve this area, but is outside of this research study.

Throughout the duration of this action research study the author has sought to influence the implementation of carbon through the project lifecycle, in doing so this has created a limitation within the study from an organisational perspective. In its success carbon has been viewed as a project problem rather than an organisational problem, the latter changes in the research study and change from capital carbon to the wider inclusion of whole life data, has mitigated this. However, other works outside of this study focus predominantly on the asset management life cycle, into which capital and whole life carbon are incorporated. This perception is influenced through the early carbon decision making and whether a project or specific project option should be taken forward, which again influences the results analysed.

10.13 Contribution to knowledge

The contribution to knowledge evidenced through this study has been focused on the areas of:

- Research in action
- A collaborative democratic partnership
- A sequence of events and approach to problem solving

Research in action, has been demonstrated through the implementation, development and future replacement of a WLCPT and how systems, tools and processes, form one part of a wider jigsaw, requiring the continued alignment of culture and behaviors, and greater regulation at both an organisational and industry level. The level of information now available for other organisations to learn from is significantly improved based upon the outputs from this study, the EA and it supply chain, who continue to proactively share their knowledge and practical examples across industry.

A collaborative democratic partnership with the organisation and its supply chain has been evidenced; through the implementation and utilization of WLCPT, this maturing journey continues outside of this research study through the implementation of a combined Cost and

Carbon Tool. Through the sequence of events and approach to problem solving in a complex adaptive organisation, the maturity of the organisation has significantly improved with EA viewed as a client organisation leading the low carbon journey.

This study has tested whether low carbon leads to low cost, this area of study will continue outside of the research study and is part of the authors, professional role. This research study has made an original contribution to knowledge, through research in action; a collaborative democratic partnership. It has expanded the knowledge base around complexity theory and action research, and evidenced how the consideration of low carbon can be practically improved. The research supports this evidence-based approach and has influence organisations within UK public sector FCRM construction and current thinking. The key study aim has investigated the prioritisation of low carbon, in the context of UK public sector FCRM construction, through the implementation and development of a whole life carbon planning tool (WLCPT). This has provided a suitable evidential context for paradigm shifts in practice, and act as the catalyst for increasing the success of low carbon initiatives and cost reduction in the UK construction industry.

10.14 Recommendations

This study has identified the following recommendations for future practical organisational activities and academic research.

Practical organisational activities:

- full implementation of combined Cost and Carbon Tool (CCT) within the organisation, to better facilitate an improved digitised systematic approach to cost and carbon quantification and low carbon decision making;
- continued governance and compliance in the provision of data throughout the asset and project life cycle from both public and private sector;
- continued awareness raising, to further improve skills and capabilities, the continuation of knowledge share through new case studies and factsheets, should be incorporated into contract requirements and undertaking project level carbon workshops should be part of the project process;

- through the implementation of CCT identify the correlation to the choices made as part of the capital solution and the effect on the operational outputs, the impact of tonnes of carbon and associated capital and operational cost;
- continued low carbon promotion to further mature this area within the organisations culture;
- further analysis of cost and carbon correlation at a more granular level, with greater alignment at and asset management level;
- further analysis of whole life cost and carbon, the role of sequestration and natural flood management techniques, utilising this data to implement solutions which may have both social and environmental net gain benefits;
- a behavioural insights review that covers both the organisation and its supply chain and how it can transition to net zero;
- continued visible leadership and low carbon promotion.

Academic research:

- to identify which roles can better influence carbon reduction and when, to better focus the actions individuals should take throughout the project life cycle, this should be aligned to the organisational criterion identified within PAS 2080 (BIS, 2016);
- impact of societal changes on acceptance of low carbon ways of working;
- to identify individual and team behavioural changes and how this can be supported to aid a better organisational change and transition to net zero;
- impact of making incentivisation techniques available within contracts to ensure that that there is both a financial incentive rather than only a quality commitment to reduce carbon;
- impact of sequestration and natural capital benefits on FCRM decision making, to ensure that there is a social, environmental and economic benefit;
- how digitalisation and improvements to information technology and data from source can aid implementation of low carbon solutions in construction;
- the role of good data and how digitisation of carbon data from source can support governance, compliance and low carbon solutions.

This action research approach has raised new questions for the author and has identified further research areas to be progressed:

- availability of knowledge sharing low carbon solutions within wider construction industry;
- how individual change can influence and affect the success level of low carbon solutions;
- influence of societal change and focus on climate change and its impacts on the construction industry;
- how digitalisation and improvements to information technology and data from source can aid implementation of low carbon solutions in construction by data sharing across client sectors;
- WLCPT and their development to net zero carbon tools;
- further review of low carbon, reduced cost and improved efficiency within construction and the continued evidencing of progress through ICR (HM Treasury, 2013) updates;
- establishment of industry wide methodology, data set, baselines and targets;
- embedding of low carbon innovation into business as usual;
- if society is demanding accountability and change, are greater risks and amendments to design standards required?
- can a circular economy approach provide a better solution to a net zero carbon challenge?
- greater alignment of carbon and cost data, one resource input to currency types (£ and CO_2) out;
- incentivisation within contractual arrangements to support the implementation of low carbon solutions.

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APPENDIX A Key Concepts – What are author s' areas of concern?

Area	Objective	My concerns	Why am I concerned	What kind of data will I gather	What can I do about it	What kind of data will I gather to show the situation as it unfolds	How will I conclude that my conclusions are reasonably fair and accurate
What is the current status on carbon within UK Public Section FCRM construction and what role does the organisation play?	OB1	Does everyone understand what 'low carbon' means and how this translates to current professional sector and organisation	Do project teams know what a low carbon solution is? And do they know how to use the current carbon tools	Current guidance and support Knowledge share and training	Find out more about low carbon and how it is currently undertaken in UK Public sector FCRM construction	Guidance and support Knowledge share and training	Increase in knowledge share across the business and supply chain
Can low carbon initiatives (including tools) influence the organisation and wider construction industry	OB2, OB3, OB4.	As a leading organisation, we are not leading the infrastructure sector on reducing carbon and making visible contributions to a better way of working. Are the current carbon tools we use suitable; can they be improved? Do we need to do better in sharing knowledge and driving the low carbon agenda?	Are we using the best practice approach to recording and calculating carbon reductions on projects, can we do better	Current tool used in FCRM, ither publically available tools Training and guidance Knowledge share and training	Find out what my organisation currently does to record carbon on construction and look at how this can be improved	Implementation on new tool Guidance and training Knowledge share	Utilisation of industry best practice whole life carbon tool
What can I do to mitigate climate change to protect the planet for future generations, within my work environment?	OB5	Climate change and doing the right thing to protect the planet for future generations is important to me at an individual level. Sustainability and carbon saving are seen as an add-on and not core to the project objectives and economics. I am aware of this from both my personal experience as a PM in UK public sector FCRM construction, whereby sustainability/environmental enhancements were only included it there was budget available and carbon was only required for reporting purposes and therefore only completed as a data return and not as an item that is integral to the decision-making process. How can I make it important to others in the workplace, who through their construction works contribute to the problem of climate change	I feel a sense of urgency and the need to do something more, but I do not think that at present my organisation is also	Survey – what is the current understanding/approach to low carbon Communications I send out Carbon reporting	Investigate ways to make a difference through positive action, putting environmentally sustainable decisions at the heart of decision making	Carbon Reporting Communications around carbon that I and others send out	Visibility of carbon as part of day to day communications. Key messages re carbon and climate change importance from management and Directors.
		Organisational culture and the accepted behaviour of individuals, will determine whether an initiative is successful and fully embedded into an organisation	How can organisational culture be fully understood to be used to influence a change in approach to low carbon construction	Survey – what is the current understanding of the organisation and its approach to low carbon Business as usual approach is carbon embedded in relevant documentation	Find out more about organisational culture and how this can be influenced to achieve a sustained change	Business as usual approach carbon embedded in relevant documentation Part of assurance approach Carbon reporting	Change across the business in promoting low carbon solutions and being part of the business as usual approach
Costs are driving project decisions; how can project teams be empowered and up-skilled to reduce carbon	OB6, OB7, OB8, OB9	Project decisions and outcomes are primarily made on the basis of cost. This means that when more environmentally sustainable and low carbon solutions are available these drivers are not being given the same level of priority	Low carbon options are not being implemented as they are seen as too costly, although ICR report says otherwise	Survey to test theory that low carbon is high cost Link carbon and cost on projects Knowledge share and training	Look at how low carbon can be better prioritised Look at how cost and carbon can be assessed jointly	Carbon and cost reporting – visualise Knowledge share	Build evidence base that there is a link between carbon and cost on FCRM projects

APPENDIX B Main survey questions April 2016

Background							
1) What sector do you work for?	Public	**2)** What gender are you?			Male		Prefer not to say
	Private				Female		
3) Which category includes your age?	Under 21	30 - 39		50 - 59		Prefer not to say	
	22 - 29	40 - 49		60 or older			
4) What is your level of experience in the UK Public Sector Flood Risk Management construction industry?			0 - 1 years	2 - 5 years	6 - 10 years	11 - 20 years	Over 20 years
5) Which of the following best describes your role in UK Public Sector Flood Risk Management Construction Projects?		Stakeholder	Client	Design/Engineering Consultant		Construction Manager	Cost Consultant
		Other Please state					
Organisational Culture and Organisational Leadership -How an individual and an organisation reacts and responds to new initiatives, may determine whether an initiative is successful in meeting its main objective. The following							
6) Please indicate how important YOU believe low carbon initiatives are to YOUR organisation (4 being extremely important and 0 being extremely unimportant)			4	3	2	1	0
7) Please indicate how important low carbon initiatives are to YOU. (4 being extremely important and 0 being extremely unimportant)			4	3	2	1	0
8) Please select to what extent you are satisfied with how your organisation have implemented, promoted and prioritised low carbon	Implemented low carbon initiatives	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
	Promoted low carbon initiatives	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
	Prioritised low carbon initiatives	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
9) Who leads on the promotion of low carbon initiatives for your organisation	Management	Another department	My line Manager	A named person	I do	I don't know	An external organisation
10) How often do you discuss low carbon initiatives on your project	Extremely often	Very often	Moderately often	Slightly often	Not often at all	Never	I don't know
11) Please tick as many items which to your knowledge best describe your organisation	My organisation has low carbon targets applied across the organisation						
	My organisation has carbon targets applied to particular customers						
	My organisation uses low carbon solutions and technologies that are shared and used by our suppliers and/or clients						
	In my organisation I find it easy to use low carbon data and information without intervention						
	My organisation receives low carbon data and information from its supply chain and/or client which allows me to promote low carbon on my projects						
	My organisation's project leaders encourage low carbon solutions and technology sharing						
	My organisation utilises low carbon data to priorities/inform project options						
	None of the above						

Appendix B Main survey questions April 2016

Question							
12) Selecting the relevant milestones please confirm at what stage is LOW CARBON PLANNING is actively discussed on your projects?	Never	At the start of a project	At Appraisal Stage	At Design Stage	At Construction Stage		At the end of the project
13) Selecting the relevant milestones please confirm at what stage is CARBON CALCULATION actively discussed on your projects?	Never	At the start of a project	At Appraisal Stage	At Design Stage	At Construction Stage		At the end of the project
14) Selecting the relevant milestones please confirm at what stage are COSTS are actively discussed on your	Never	At the start of a project	At Appraisal Stage	At Design Stage	At Construction Stage		At the end of the project
15) Are you satisfied with the level of low carbon training you have received?		Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
16) Please select 1 statement that best reflects how often and to what level of detail you think your organisation should check on whether an initiative has been implemented correctly	Always we can't trust individuals to do what they are told						
	In depth regular spot checks only when we think there is a problem						
	High level regular checks at the beginning then reduce the frequency of checks						
	High level spot checks only when we think there is a problem						
	In depth spot checks at the beginning leading to high level spot checks regularly						
	Never we can trust individuals to do as they are told						
	I don't know						
17) In YOUR opinion what mechanisms would have the most impact in changing behaviours and getting the best low carbon outcomes? (4 being the extremely highest impact and 0 being the extremely lowest impact)	Low carbon targets		4	3	2	1	0
	Low carbon incentives		4	3	2	1	0
	A contractual agreement		4	3	2	1	0
	Quantitive consideration as part of the option selection		4	3	2	1	0
	Qualitative consideration during appraisal/approval		4	3	2	1	0
18A) How often do you report on low carbon lessons learnt		Extremely often	Very often	Moderately often	Slightly often	Not often at all	Never
18B) How often do you report on low carbon best practice		Extremely often	Very often	Moderately often	Slightly often	Not often at all	Never
18C) How often do you utilise low carbon lessons learnt		Extremely often	Very often	Moderately often	Slightly often	Not often at all	Never
18D) How often do you utilise low carbon best practice		Extremely often	Very often	Moderately often	Slightly often	Not often at all	Never
19) Please rate the following statements to reflect how successful YOU feel your organisation is in managing change	Responds to major change	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
	Responds to minor change	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
	Implements change in a timely manner	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
	Implements change in a controlled manner	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied
	Discusses new changes with staff	Extremely satisfied	Very satisfied	Moderately satisfied	Slightly satisfied	Moderately dissatisfied	Extremely dissatisfied

Appendix B Main survey questions April 2016

20) Please tick 1 statement that best reflects your views	I don't like change						
	I like some change as long as it is planned and implemented slowly						
	I like some change that I can react to and implemented quickly						
	I like some change as long as it is planned and implemented quickly						
	I like lots of change as long as it is planned and implemented slowly						
	I like lots of change that I can react to and implement quickly						
	I don't know						
21) Is your organisation's response to implementing change better, worse or about the same as other Government construction sector suppliers and/or clients?	Much better	Somewhat better	Slightly better	About the same	Slightly worse	Somewhat worse	Much Worse
22) In your experience do low carbon solutions cost more, less or similar to other conventional solutions?	Much better	Somewhat better	Slightly better	About the same	Slightly worse	Somewhat worse	Much Worse
Thank you for your time							

APPENDIX C Main survey responses

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Main Approach		Survey											
2	Mean score		VAR 2 36.41%		VAR 3 42.0%		VAR 4 58.06%		VAR 5 55.00%		VAR 6 61.28%		VAR 7 60.28	
3	VAR 1 demography of professionals		Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value	Mean score for each category	P value
4	Sector	Public n = 39	35.18	0.28	46.98	0.58	60.27	0.48	54.14	0.45	60.79	0.33	61.32	0.49
5		Private n = 58	41.09		46.41		41.09		58.21		63.61		59.47	
6	Gender	Male n = 71	37.24	0.47	45.79	0.97	55.75	0.97	56.62	0.23	61.44	0.82	59.80	0.65
7		Female n = 21	33.29		45.70		65.87		49.52		60.71		63.27	
8	Age	Young age n = 42	36.46	0.98	45.10	0.46	62.20	0.16	52.20	0.33	58.31	**0.04**	58.03	0.16
9		Old age n = 50	36.35		46.31		54.74		57.25		63.66		63.31	
10	Experience	Short experience n = 45	35.85	0.82	46.34	0.51	62.31	0.10	55.00	0.98	60.08	0.50	62.60	0.26
11		Long experience n = 47	36.95		45.24		53.57		55.10		61.85		58.83	
12	Role	Client/other n = 40	41.18	0.08	47.01	0.20	53.66	0.17	61.00	**0.02**	61.48	0.89	62.50	0.33
13		supply chain n = 52	32.12		44.82		60.90		49.43		61.12		58.57	

Appendix C Main survey responses VAR 1

	A	B	C	D	E	F
1	**VAR 1 demography of professionals**					
2		Q 1	Q2	Q3	Q4	Q5
3 4		What sector do you work for?	What gender are you?	Which category includes your age?	What is your level of experience in the UK Public Sector Flood Risk Management construction industry?	Which of the following best describes your role in UK Public Sector Flood Risk Management construction projects?
5		Private = 1, Public = 2	Male = 1, Female = 2, Prefer not to say = 3	Under 21 = 1, 21 - 29 = 2, 30 - 39 = 3, 40 - 49 = 4, 50 - 59 = 5, 60 and over = 6, Prefer not to say = 7	0 - 1 years = 1, 2 - 5 years = 2, 6 - 10 years = 3, 11 - 20 years = 4, over 20 years = 5	Stakeholder = 1, Client = 2, Design/engineering consultant = 3, Construction Manager = 4, Cost Consultant = 5, Other = 6
6	1	1	1	6	4	3
7	2	2	1	3	3	2
8	3	2	2	3	3	2
95	90	1	1	3	3	4
96	91	2	2	4	2	3
97	92	1	1	4	3	4
148	Count	92	92	92	92	92
149	Sum	129	114	356	247	329
150	Mean	1.40	1.24	3.87	2.68	3.58
151	Percentage	70	41	55	54	60
152		Countif Private =	Countif Male =	Countif Under 21 =	Countif 0 - 1 years =	Countif stakeholder =
153		55	71	0	13	1
154		Countif Public =	Countif Female =	Countif 21 - 29 =	Countif 2 - 5 years =	Countif Client =
155		37	20	7	32	26
156			Countif Prefer not to say =	Countif 30 - 39 =	Countif 6 - 10 years =	Countif Design/engineering consultant =
157			1	33	27	21
158				Countif 40 - 49 =	Countif 11 - 20 years =	Countif Construction Manager =
159				31	11	20
160				Countif 50 - 59 =	Countif over 20 years =	Countif Cost Consulant =
161				9	9	11
162				Countif 60 and over =		Countif Other =
163				10		13
164				Countif Prefer not to say =		
165				2		

Appendix C Main survey responses VAR 2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	**VAR 2 low carbon prioritisation**																		
2	No of return	Q11 Please select as many items which to your knowledge best describe your organisation										Q12 Selecting the relevant milestones please confirm at what stage is LOW CARBON PLANNING actively discussed on your projects?							
3		My organisation has low carbon targets which are applied across the organisation	My organisation has low carbon targets applied to particular customers	My organisation uses low carbon solutions and technologies that are shared and used by our suppliers and/or clients	In my organisation I find it easy to use low carbon data and information without intervention	My organisation receives low carbon data and information from its supply chain and/or client which allows you to bring it together with other data to promote low carbon on our projects	My organisation's project leaders encourage low carbon solution and technology sharing	My organisation utilises low carbon data to prioritise/inform project options	None of the above	Total	%	Never	At the start of a project	At appraisal stage	At design stage	At construction stage	At the end of a project	Total	%
4		7	1	3	2	4	5	6	0			0 = no, 1= yes							
5	1	0	0	0	0	4	5	0	0	9.00	32.14	0	0	0	1	1	1	3.00	60.00
6	2	7	1	3	0	4	5	6	0	26.00	92.86	0	0	1	0	0	0	1.00	20.00
7	3	7	0	3	0	4	5	0	0	19.00	67.86	0	0	1	0	0	0	1.00	20.00
94	90	0	0	0	0	0	5	0	0	5.00	17.86	0	0	1	1	1	0	3.00	60.00
95	91	7	0	0	0	0	0	0	0	7.00	25.00	1	0	0	0	0	0	1.00	20.00
96	92	7	0	0	0	0	0	0	0	7.00	25.00	1	0	0	0	0	0	1.00	20.00
97	Count	92	92	92	92	92	92	92	92	Total		92	92	92	92	92	92	Total	
98	Sum	364	15	108	6	84	180	180	0			12	21	43	32	38	13		
99	Mean	3.96	0.16	1.17	0.07	0.91	1.96	1.96	0.00	10.18	36.37	0.13	0.23	0.47	0.35	0.41	0.14	1.73	34.57
100	Percentage	**56.52%**	**16.30%**	**39.13%**	**3.26%**	**22.83%**	**39.13%**	**32.61%**	**14.13%**	**36.37**	36.37	**14.18%**	**24.81%**	**50.80%**	**37.81%**	**44.90%**	**15.36%**	**34.57**	34.57
101	Median	7	0	0	0	0	0	0				0	0	0	0	0	0		
102	Mode	7	0	0	0	0	0	0				0	0	0	0	0	0		
103	Minimum	0	0	0	0	0	0	0				0	0	0	0	0	0		
104	Maximum	7	1	3	2	4	5	6				1	1	1	1	1	1		
105	Range	7	1	3	2	4	5	6				1	1	1	1	1	1		
106	SD	3.49	0.37	1.47	0.36	1.69	2.45	2.83	0.00			0.34	0.42	0.50	0.48	0.50	0.35		
107		Countif 7 =	Countif 1 =	Countif 3 =	Countif 2 =	Countif 4 =	Countif 5 =	Countif 6 =	Countif 0 =			Countif Never =	Countif At the Start of a project =	Countif At appraisal stage =	Countif At design stage =	Countif At construction stage =	Countif At the end of a project =		
108		52.00	15.00	36.00	3.00	21.00	36.00	30.00	13.00			12.00	21.00	43.00	32.00	38.00	13.00		

Appendix C Main survey responses VAR 2

VAR 2 low carbon prioritisation										
No of return	Q13 Selecting the relevant milestones please confirm at what stage is CARBON CALCULATION actively discussed on your projects?								All Q Total (Q11+Q12+Q13)	%
	Never	At the start of a project	At appraisal stage	At design stage	At construction stage	At the end of a project	Total	%		
	0 = no, 1 = yes									
1	0	0	0	1	1	1	3.00	60.00	15.00	39.47
2	0	0	0	1	0	1	2.00	40.00	29.00	76.32
3	0	0	0	0	0	1	1.00	20.00	21.00	55.26
90	0	0	1	1	1	0	3.00	60.00	11.00	28.95
91	0	0	1	1	0	0	2.00	40.00	10.00	26.32
92	0	0	1	1	1	0	3.00	60.00	11.00	28.95
Count	92	92	92	92	92	92	Total		All Q Total	
Sum	8	18	31	42	52	26				
Mean	0.09	0.20	0.34	0.46	0.57	0.28	1.92	38.48	13.84	36.41
Percentage	**9.45%**	**21.27%**	**36.63%**	**49.62%**	**61.44%**	**30.72%**	**38.48**	769.57	**36.41**	95.82
Median	0	0	0	0	1	0				
Mode	0	0	0	0	1	0				
Minimum	0	0	0	0	0	0				
Maximum	1	1	1	1	1	1				
Range	1	1	1	1	1	1				
SD	0.28	0.40	0.48	0.50	0.50	0.45				
	Countif Never =	Countif At the Start of a project =	Countif At appraisal stage =	Countif At design stage =	Countif At construction stage =	Countif At the end of a project =				
	8.00	18.00	31.00	42.00	52.00	26.00				

Appendix C Main survey responses VAR 3

VAR 3 organisational change															
No of return	Q16 Please select 1 statement that best reflects how often and to what level of detail you think your organisation should check on whether an initiative has been implemented correctly		Q17 In YOUR opinion what mechanisms would have the most impact in changing behaviours and getting the best low carbon outcomes?							Q18 How often do you report on and utilise low carbon lessons learnt and best practice?					
		%	Low carbon targets	Low carbon incentives	A contractual agreemnt	Quantitive consideration as part of the option selection criteria/formula	Qualitative consideration during appraisal/ approval process	Total	%	Report on low carbon lessons learnt	Report on low carbon best practice	Utilise low carbon lessons learnt	Utilise low carbon best practice	Total	%
	6 = Never we can trust individuals to do what they are told, 5 = High level spot checks only when we think there is a problem, 4 = Indepth regular spot checks only when we think there is a problem, 3 = High level regular spot checks at the beginning then reduce the frequency of checks, 2 = In depth spot checks at the beginning leading to high level spot checks regularly, 1 = Always, we can't trust individuals to do what they are told, 0 = I don't know		4 being the extremely highest impact and 0 being the extremely lowest impact	4 being the extremely highest impact and 0 being the extremely lowest impact	4 being the extremely highest impact and 0 being the extremely lowest impact	4 being the extremely highest impact and 0 being the extremely lowest impact	4 being the extremely highest impact and 0 being the extremely lowest impact			5 = Extremly often, 4 = Very often, 4 = Moderately often, 2 = Slightly often, 1 = Not often at all, 0 = Never	5 = Extremly often, 4 = Very often, 4 = Moderately often, 2 = Slightly often, 1 = Not often at all, 0 = Never	5 = Extremly often, 4 = Very often, 4 = Moderately often, 2 = Slightly often, 1 = Not often at all, 0 = Never	5 = Extremly often, 4 = Very often, 4 = Moderately often, 2 = Slightly often, 1 = Not often at all, 0 = Never		
1	2	33.33	1	3	3	3	2	12.00	60.00	3	3	2	2	10.00	50.00
2	2	33.33	3	2	4	1	1	11.00	55.00	1	2	2	2	7.00	35.00
3	4	66.67	4	4	3	3	2	16.00	80.00	1	1	1	1	4.00	20.00
90	4	66.67	1	2	0	4	3	10.00	50.00	1	1	1	1	4.00	20.00
91	3	50.00	4	4	3	4	4	19.00	95.00	0	0	0	0	0.00	0.00
92	3	50.00	4	4	3	4	3	18.00	90.00	0	0	0	0	0.00	0.00
Count	92	Total	92	92	92	92	92	Total		92	92	92	92	Total	
Sum	280		255	293	274	243	206			125	119	125	139		
Mean	3	50.72	3	3	3	3	2	13.82	69.08	1	1	1	2	5.52	27.61
Percentage	**50.72**	845.41	**69**	**80**	**74**	**66**	**56**	**69.08**	345.38	27	26	27	30	**27.61**	552.17
Median	3		3	3	3	3	2			1	1	1	1.5		
Mode	4		3	4	3	3	2			1	1	1	2		
Minimum	0		0	0	0	0	0			0	0	0	0		
Maximum	6		4	4	4	4	4			5	5	5	5		
Range	6		4	4	4	4	4			5	5	5	5		
SD	1.37		0.90	0.85	0.96	0.99	1.02			1.50	1.04	1.05	1.09		
	Countif 6 =		Countif 4 =	Countif 4 =	Countif 4 =	Countif 4 =	Countif 4 =			Countif 5 =	Countif 5 =	Countif 5 =	Countif 5 =		
	3.00		19.00	39.00	29.00	17.00	10.00			0.00	0.00	0.00	0.00		
	Countif 5 =		Countif 3 =	Countif 3 =	Countif 3 =	Countif 3 =	Countif 3 =			Countif 4 =	Countif 4 =	Countif 4 =	Countif 4 =		
	3.00		36.00	29.00	39.00	34.00	23.00			3.00	0.00	1.00	2.00		
	Countif 4 =		Countif 2 =	Countif 2 =	Countif 2 =	Countif 2 =	Countif 2 =			Countif 3 =	Countif 3 =	Countif 3 =	Countif 3 =		
	36.00	20.65%	29.00	20.00	16.00	28.00	37.00			13.00	16.00	15.00	17.00		
	Countif 3 =		Countif 1 =	Countif 1 =	Countif 1 =	Countif 1 =	Countif 1 =			Countif 2 =	Countif 2 =	Countif 2 =	Countif 2 =		
	19.00		5.00	2.00	3.00	9.00	16.00			13.00	19.00	22.00	27.00		
	Countif 2 =		Countif 0 =	Countif 0 =	Countif 0 =	Countif 0 =	Countif 0 =			Countif 1 =	Countif 1 =	Countif 1 =	Countif 1 =		
	21.00		1.00	0.00	3.00	2.00	4.00			37.00	33.00	32.00	26.00		
	Countif 1 =									Countif 0 =	Countif 0 =	Countif 0 =	Countif 0 =		
	0.00									25.00	24.00	22.00	20.00		
	Countif 0 =														

Appendix C Main survey responses VAR 3

	A	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
1		VAR 3 organisational change																	
2	No of return	Q19 Please rate the following statements to reflect how successful your organisation is in managing change							Q20) Please tick 1 statement that best reflects your views									All Total Questions	%
3		Responds to major changes	Responds to minor changes	Implements change in a timely manner	Implements change in a controlled and programmed timescale	Discussed new changes with staff	Total	%	I don't like change	I like some change as long as it is planned and	I like some change, that I can react to and implement quickly	I like some change as long as it is planned and	I like lots of change as long as it is planned and	I like lots of change that I can react to and implement	I don't know	Total	%		
4		5 = Extremly Satisfied, 4 = Moderately Satisfied, 4 = Slightly Satisfied, 2 = Slightly Disatisfied, 1 = Moderately Disatisfied, 0 = Extremly Disatisfied	5 = Extremly Satisfied, 4 = Moderately Satisfied, 4 = Slightly Satisfied, 2 = Slightly Disatisfied, 1 = Moderately Disatisfied, 0 = Extremly Disatisfied	5 = Extremly Satisfied, 4 = Moderately Satisfied, 4 = Slightly Satisfied, 2 = Slightly Disatisfied, 1 = Moderately Disatisfied, 0 = Extremly Disatisfied	5 = Extremly Satisfied, 4 = Moderately Satisfied, 4 = Slightly Satisfied, 2 = Slightly Disatisfied, 1 = Moderately Disatisfied, 0 = Extremly Disatisfied	5 = Extremly Satisfied, 4 = Moderately Satisfied, 4 = Slightly Satisfied, 2 = Slightly Disatisfied, 1 = Moderately Disatisfied, 0 = Extremly Disatisfied			6	5	4	3	2	1	0				
5	1	4	4	4	4	4	20.00	80.00	0	5	0	0	0	0	0	5	23.81	49.00	53.26
6	2	4	4	2	2	2	13.00	52.00	0	5	0	0	0	0	0	5	23.81	38.00	41.30
7	3	5	3	3	5	4	19.00	76.00	0	0	4	0	0	0	0	4	19.05	47.00	51.09
34	30	3	3	3	3	3	23.00	92.00	0	0	4	0	0	0	0	4	19.05	45.00	48.91
35	31	5	4	5	5	4	0.00	0.00	0	0	0	0	0	1	0	1	4.76	23.00	25.00
36	32	5	4	5	5	4	0.00	0.00	0	0	0	3	0	0	0	3	14.29	24.00	26.09
18	Count	32	32	32	32	32	Total		32	32	32	32	32	32	32	Total		All Q Total	
19	Sum	329	334	301	310	280			24	85	48	117	14	7					
20	Mean	4	4	3	3	3	16.52	66.09	0.26	0.92	0.52	1.27	0.15	0.08		3	15	42.11	45.77
21	Percentage	72	73	65	67	61	**66.09**	1321.74	4	18	13	42	8	8		**15**	254	**80.98**	762.84
22	Median	4	4	3	4	3			0	0	0	0	0	0					
23	Mode	4	4	3	4	3			0	0	0	0	0	0					
24	Minimum	0	0	0	0	0			0	0	0	0	0	0					
25	Maximum	5	5	5	5	5			5	5	5	5	5	5					
26	Range	5	5	5	5	5			5	5	5	5	5	5					
27	SD	0.89	0.72	0.94	0.97	1.00			1.23	1.95	1.35	1.49	0.53	0.27					
28		Countif 5 =	Countif 5 =	Countif 5 =	Countif 5 =	Countif 5 =			Countif 6 =	Countif 5 =	Countif 4 =	Countif 3 =	Countif 2 =	Countif 1 =	Countif 0 =				
29		9.00	5.00	4.00	5.00	5.00			4.00	17.00	12.00	39.00	7.00	7.00	0.00				
30		Countif 4 =	Countif 4 =	Countif 4 =	Countif 4 =	Countif 4 =													
31		46.00	54.00	37.00	44.00	25.00													
32		Countif 3 =	Countif 3 =	Countif 3 =	Countif 3 =	Countif 3 =													
33		31.00	29.00	38.00	30.00	39.00													
34		Countif 2 =	Countif 2 =	Countif 2 =	Countif 2 =	Countif 2 =													
35		1.00	2.00	6.00	6.00	15.00													
36		Countif 1 =	Countif 1 =	Countif 1 =	Countif 1 =	Countif 1 =													
37		5.00	2.00	7.00	7.00	8.00													
38		Countif 0 =	Countif 0 =	Countif 0 =	Countif 0 =	Countif 0 =													
39		0.00	0.00	0.00	0.00	0.00													

Appendix C Main survey responses VAR 4

	A	B	C	D	E
1	**VAR 4 organisational carbon leadership**				
2–4	No of returns	Q9 Who leads on the promotion of low carbon initiatives for your organisation?	Q21 Is your organisation's response to implementing change better, worse or about the same as other Government construction sector suppliers and/or clients?	All Q Total	%
		6 = A named person, 5 = I do as part of my role, 4 = Upper management, 3 = My line manager, 2 = Another department, 1 = An external organisation, 0 = I don't know	6 = Much better, 5 = Somewhat better, 4 = Slightly better, 3 = About the same, 2 = Slightly worse, 1 = Somewhat worse, 0 = Much worse		
5	1	0	3	3	25.00
6	2	5	5	10	83.33
7	3	0	3	3	25.00
94	90	0	4	4	33.33
95	91	5	5	10	83.33
96	92	5	3	8	66.67
97	Count	92	92	All Q Total	
107		Countif Upper management =	Countif Much better =	6.97	58.06
108		25	10	**58.06**	483.85
109		Countif Another department =	Countif Somewhat better =		
110		17	21		
111		Countif My line manager =	Countof Slightly better =		
112		0	29		
113		Countif A named person =	Countif About the same =		
114		9	32		
115		Count if I do =	Countif Slightly worse =		
116		1	1		
117		Countif and external organisation	Countif Somewhat worse =		
118		0	0		
119		Counti if I don't know	Countif Much worse =		
120		40	0		

Appendix C Main survey responses VAR 5

VAR 5 Type of Training			
No of return	Q 15 Are you satisfied with the level of low carbon training you have received [Low carbon training]	Total	%
	0 = extremely dissatisfied, 1 = moderately dissatisfied, 2 = slightly dissatisfied, 3 = slightly satisfied, 4 = moderately satisfied, 5 = extremely satisfied		
1	4	4	80
2	4	4	80
3	4	4	80
90	1	1	20
91	3	3	60
92	3	3	60
Count	92	92	92
	Countif Extremely satisfied =	2.75	55
	2	**55**	1100
	Countif Moderately satisfied =		
	29		
	Countif Slightly satisfied =		
	24		
	Countif Moderately dissatisfied =		
	15		
	Countif Extremely disatisfied =		
	2		

Appendix C Main survey responses VAR 6

	A	B	C	D	E	F	G	H	I	J	K
1	VAR 6 organisational culture										
2		Q6 Please indicate how important YOU believe low carbon initiatives are to YOUR ORGANISATION	Q7 Please indicate how important low carbon initiatives are to YOU	Q8 Please select to what extent you are satisfied with how your organisation have implemented, promoted and prioritised low carbon					Q10 How often do you discuss low carbon initiatives on your projects?		
3	No of return			Q8a Implemented low carbon initiatives	Q8b Promoted low carbon initiatives	Q8c Prioritised low carbon initiatives	Total	%		All Q Total	%
4		4 = Extremly important, 3 = Important, 2 = Neutral, 1 = Unimportant, 0 = Extremly unimportant	4 = Extremly important, 3 = Important, 2 = Neutral, 1 = Unimportant, 0 = Extremly unimportant	5 = Extremly satisfied, 4 = Moderately satisfied, 3 = Slightly satisfied, 2 = Slightly unsatisfied, 1 = Moderately unsatisfied, 0 = Extremly unsatisfied	5 = Extremly satisfied, 4 = Moderately satisfied, 3 = Slightly satisfied, 2 = Slightly unsatisfied, 1 = Moderately unsatisfied, 0 = Extremly unsatisfied	5 = Extremly satisfied, 4 = Moderately satisfied, 3 = Slightly satisfied, 2 = Slightly unsatisfied, 1 = Moderately unsatisfied, 0 = Extremly unsatisfied			6 = Much better, 5 = Somewhat better, 4 = Slightly better, 3 = About the same, 2 = Slightly worse, 1 = Somewhat worse, 0 = Much worse		
5	1	3	2	4	4	4	12	0.80	5	22.00	68.75
6	2	4	2	3	3	3	9	0.60	5	20.00	62.50
7	3	4	3	5	5	5	15	1.00	4	26.00	81.25
94	90	4	3	4	4	4	12	0.80	3	22.00	68.75
95	91	4	4	4	4	4	12	0.80	6	26.00	81.25
96	92	4	4	4	4	4	12	0.80	6	26.00	81.25
115	Count	92	92	92	92	92	Total		92	All Q Total	
125		Countif Extremely important =	Countif Extremely important =	Countif Extremely satisfied =	Countif Extremely satisfied =	Countif Extremely satisfied =	9.36	0.62	Countif Much better =	19.61	61.28
126		32	19	3	3	2	**62.39**	4.16	12	**61.28**	211.30
127		Countif Important =	Countif Important =	Countif Moderately satisfied =	Countif Moderately satisfied =	Countif Moderately satisfied =			Countif Somewhat better =		
128		33	54	29	32	27			32		
129		Countif Neutral =	Countif Neutral =	Countif Slightly satisfied =	Countif Slightly satisfied =	Countif Slightly satisfied =			Countif Slightly better =		
130		23	17	46	39	40			22		
131		Countif Unimportant =	Countif Unimportant =	Countif Slightly unsatisfied =	Countif Slightly unsatisfied =	Countif Slightly unsatisfied =			Countif About the same =		
132		4	2	10	14	19			20		
133		Countif Extremely unimportant =	Countif Extremely unimportant =	Countif Moderately unsatisfied =	Countif Moderately unsatisfied =	Countif Moderately unsatisfied =			Countif Slightly worse =		
134		0	0	3	3	2			6		
135				Countif Extremely unsatisfied =	Countif Extremely unsatisfied =	Countif Extremely unsatisfied =			Countif Somewhat worse =		
136				1	1	2			0		
137									Countif Much worse =		
138									0		
139											

Appendix C Main survey responses VAR 7

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	VAR 7 Cost												
2		Q14 Selecting the relevant milestones please confirm at what stage is COST actively discussed on your projects?						Total	%	Q 22 In your opinion do low carbon solutions cost more, less or similar to other conventional solutions?	%	All Q Total	%
3		Never	At the start of a project	At appraisal stage	At design stage	At construction stage	At the end of a project			Much better = 6, Somwhat better = 5, Slightly better = 4, About the same = 3, Slightly worse = 2, Somewhat worse = 1, Much worse = 0			
4	No of returns	0 = no, 1 = yes											
5	1	0	0	1	1	1	0	3	60	3	50.00	6	54.55
6	2	0	1	1	1	1	1	5	100	3	50.00	8	72.73
7	3	0	0	1	0	1	0	2	40	4	66.67	6	54.55
94	90	0	0	1	1	1	1	4	80	4	66.67	8	72.73
95	91	0	0	1	1	1	1	4	80	4	66.67	8	72.73
96	92	0	1	1	1	1	1	5	100	4	66.67	9	81.82
97	Count	92	92	92	92	92	92	Total		92	Total	All Q Total	
98	Sum	4	50	51	56	63	56			330.00			
99	Mean	0.04	0.54	0.55	0.61	0.68	0.61	3.04	60.87	3.59	59.78	6.63	60.28
00	Percentage	**4**	**54**	**55**	**61**	**68**	**61**	**60.87**	1217	**59.78**	996.38	**60.28**	548
01	Median	0.00	1.00	1.00	1.00	1.00	1.00			4.00			
02	Mode	0	1	1	1	1	1			4			
03	Minimum	0	0	0	0	0	0			0			
04	Maximum	1	1	1	1	1	1			5			
05	Range	1	1	1	1	1	1			5			
06	SD	0.21	0.50	0.50	0.49	0.47	0.68			1.10			
07		Countif Never =	Countif At the start of a project =	Countif At appraisal stage =	Countif At design stage =	Countif At construction stage =	Countif At the end of a project =			Countif Much better =			
08		4	50	51	56	63	51			6			
09										Countif Somewhat better =			
10										6			
11										Countif Slightly better =			
12										40			
13										Countif About the same =			
14										27			
15										Countif Slightly worse =			
16										11			
17										Countif Somewhat worse =			
18										1			
19										Countif Much worse =			
20										1			

APPENDIX D Action Research Timeline 2013 - 2020
2013/July to 2016/March

Year/Month	Activities	Comments
2013/July	PhD Commenced	Commencement of literature review and refinement of subject area.
2014/May	Pilot Survey Carried Out	Appendix B
2014/September	Paper to ncpms Management Team	Appendix 5 Proposal paper
2014/October	Main survey carried out	Appendix B
2014/November	£70k funding secured from FCRM for replacement whole life carbon planning tool	Supporting Benefits paper. Funding approval email, Project procurement strategy and project funding mandate
2014/December	Tender and award to National Cost Management Framework supplier	Project scope form Award of delivery contract
2015/January	Carbon Communications	Current magazine article
2015/March	Whole life carbon tool works completed	End of delivery contract Delivered documents
2015/March	Shortlisted for Women in Construction Green Leadership Award	Shortlisted Green Leadership Award promoting the implementation of the Whole life carbon tool within the EA.
2015/April – 2016/January	Soft Launch - Whole life carbon planning tool rolled out	Roll out of main Whole life carbon planning tool for major projects and Carbon LITE for Minor works and in-house construction projects Appendix G Training slides
2015/ May – 2015/October	Career break	
2015/September	IPGRC conference paper	Appendix I IPGRC conference paper, 'Change Management to Attain Efficiencies'
2016/February	Presentation for 2016 Flood and Coast event	Presentation Main slot, Presentation Theatre slot
2016/February	Presentation Carbon Planning Tools Webinar presentation	Presentation slides Carbon Planning Tools Webinar presentation
2016/February	Carbon Presentations	Flood and coast main and theatre presentation slots
2016/March	Shortlisted for Women in Construction Green Leadership Award	Shortlisted Green Leadership Award promoting the implementation of the Whole life carbon tool within the EA.
2016/March	Paper to ncpms MT	Advocating continued leadership and support. Who will maintain and manage the tool – Result permanent role to lead implementation of Whole life carbon planning tool created on an assignment basis

Timeline April 2016 – March 2017

Year/Month	Action	Comments
2016/April	Salford University Low carbon Economy seminar	Networking contact with Natural Resources Wales and promotion of use of Environment Agency Tool
2016/April	Carbon communications	Carbon cascade slide ncpms
2016/May	Infrastructure Carbon Review seminar	Attendance update on ICR principles signatory's and progress with ICR commitments
2016/May	Carbon Planning Tool Training	Training sessions held with TE2100
2016/June	Environment Agency Supply Chain Conference	Carbon presentation
2016/June	Forum for the future seminar	Attendance Forum for the future seminar – Sustainability: a dirty word?
2016/June	Carbon communications	Carbon cascade slide ncpms and webinar presentation
2016/July	Carbon communications	Carbon cascade slide ncpms
2016/August	Carbon Planning Manager	New role commenced on assignment for 8 months.
2016/August	Carbon presentations	Update to commercial team on carbon process Update to FCRM Steering Group on carbon reporting
2016/August	Carbon communications	Carbon article Field Services Magazine
2016/August	Carbon communications	Statement of Principles memos, covering capital projects, 5 case business case and reporting
2016/September	Carbon LITE	Rollout of Carbon LITE version of the tool
2016/September	Carbon communications	Cascade slide to ncpms – Call for carbon champions F2F carbon training Team 2100
2016/September	Ops manager presentation	Presentation to Ops managers re carbon update
2016/November	Supplier Conference presentation	Low carbon, reduced cost, improved efficiency presentation at EA supplier conference
2016/November	Carbon presentation	FCRM Steering Group carbon update
2016/November	.gov	Update of text and links to.gov.uk webpage
2016/October	Carbon communications	FCRM Needs to Know
2016/October	Carbon communications	Linking Carbon cost and efficiency
2016/October	ncpms Memo	Carbon baseline memo for ncpms management team
2016/October	NRW carbon tool training	Face to face training Natural Resources Wales
2016/November	Field services magazine	Carbon article
2016/November	FCRM steering group presentation	Carbon update TO FCRM Steering Group
2016/November	Baseline	Back log of carbon baselines produced.
2016/December	Naming the Carbon Tool	Eric naming competition, and logo design

2016/December	Low carbon, reduced cost, improved efficiency	WEM paper
2016/December	IEM presentation	Carbon update to Internal Environment Management
2017/January	Promotional material	Securing £5k for Eric promotional material mouse matts and coasters
2017/January	Carbon communications	Current Magazine article
2017/February	NEAS presentation	Carbon update to National Environmental Assessment service
2017/February	Procurement presentation	Carbon update to Procurement
2017/February	Carbon communications	Buzz update – Meet Eric
2017/February	Flood and Coast	Carbon, cost and efficiency producing presentation at Flood and Coast 2017 (delivered by others)

Timeline April 2017 – March 2018

Year/Month	Action	Comments
2017/May	Carbon communications	Cascade slide ncpms
2017/June – 2017/October	Career break	
2017/October	NPAS presentation Carbon communications	Carbon update to National Project Assurance Service Carbon Catch up calls set up – run every 6 weeks
2017/November	Construction climate challenge presentation	Presentation at the Volvo Construction Climate Challenge, seminar and plenary discussions, along with 2 video updates on EA Eric work.
2017/November	Eric assurance Review	Contract awarded
2018/January	Carbon communications	Cascade slide ncpms
2018/January	Carbon communications	Project Delivery Unit Carbon Reduction Plans
2018/January	e-learning	Contract commencement for e-learning module
2018/February	Report complete	Eric review
2018/February – 2018/March	Implementing low carbon workshops	Best practice report, case studies, fact sheets and presentation

Timeline April 2018 – March 2019

Year/Month	Action	Comments
2018/April – 2018/October	16 Low carbon Workshops	Low carbon solutions workshops facilitated by Carbon Trust
2018/April	Networking	New Civil Engineer and Mott McDonald round table discussion
2018/April	Carbon Communications	Current Magazine Article; Cascade slides for ncpms and NEAS training
2018/May	Carbon Communications	Easinet carbon text update; gov.uk carbon text update; awareness of Low carbon workshop training for suppliers and EA staff
2018/May	Papers	ncpms management team paper and Carbon efficiency paper for FCRM
2018/June	Networking	Low carbon concrete workshop
2018/July - 2019/March	Low carbon future programme contract awarded	Review of: • Minimum Technical Requirements • Carbon budget • Natural Flood management case studies • Carbon, cost and efficiency review
2018/July	Judge	British Construction Industry awards
2018/August	e-learning live	e-learning module available for EA staff and external suppliers
2018/September	Review meeting	5 Case business case implementation review workshops
2018/September	Presentation	Local Delivery Leads - carbon reduction in operations
2018/September – 2019/March	Cost and Carbon Tool	Role Project Executive and Senior user for carbon
2019/January	Knowledge share	How EA has set and monitored Carbon targets - Heathrow
2019/February	Carbon Day	Workshop for EA staff and external suppliers
2019/February	Knowledge share	I3P Advanced material development (chemistry/infrastructure industry) collaboration workshop
2019/March	Capital Carbon Maturity review	Report accepted by business
2019/March	Knowledge share	How EA has set and monitored Carbon targets - HS2
2019/March	Presentation	Bolton University

April 2019 to June 2020

Year/Month	Action	Comments
2019/April	Training	CEEQUAL awareness
2019/April –July	European funding bid	Low carbon procurement, knowledge share
2019/May	Presentation	National Construction expo Cost and Carbon
2019/May	Presentation	Inventory Carbon (embodied) database roll out
2019/June	Presentation and Carbon stand	Flood and Coast Conference 2019
2019/June	Presentation	Strategic Leaders
2019/September	Working group	I3P Review of PAS 2080, sharing of evidence, knowledge share
2019/November	I3P carbon workshop	Knowledge share workshop
2019/November	Government construction client Capability Group – Presentation	Presentation on Environment Agency's carbon journey
2019/November	Infrastructure Projects Authority - workshop	Running an IPA decarbonisation session at the Project Score Card Workshop
2019/November	Seminar	Carbon 2050 construction news seminar
2019/November	Feedback	Infrastructure Carbon Review, Environment Agency feedback on progress and feedback on PAS 2080 standard
2019/November	Seminar and Panel expert	Mott MacDonald Carbon Crunch: Delivering infrastructure for net zero
2019/November	Environment and Business Carbon and Sustainability workshop	Participant supporting wider business areas
2019/December	Environment Agency two-day Carbon Expo	Presentation on Environment Agency Low Carbon Journey; Eric Stand; Chair of two sessions
2019/December	Conference paper and presentation	14^{th} international Post Graduate Research conference 2019. University of Salford Manchester.
2019/January – December	Project Executive Cost and Carbon Tool	Project Executive for the new Cost and Carbon Tool replacing Eric and PCT
2020/January	New role	Programme Carbon and Cost Manager
2020/January - June	UNSDG Design team	Part of design team to implement UNSDG process into current reporting processes
2019/January – 2020/June	Senior User Cost and Carbon Tool	Project Executive for the new Cost and Carbon Tool replacing Eric and PCT
2020/May	Chair ICE COP 26 work stream 1	Chair Work stream 1
2020/June	Keynote speaker	London South Bank University
2020/June	Women in Engineering Society	Women in Engineering Society Sustainability Winner 2020
2020 July	ICE Carbon project	Workstream 1 chair

APPENDIX E Communications and Reports 2016 - 2019

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easinet

Home

Policies and procedures

Environmental work

Sustainable business

Footprint

Energy and carbon

ERIC carbon planning tool

ERIC carbon planning tool

ERIC is our carbon planning tool which shows how much carbon will be produced by a particular construction project and, by making changes, how we can reduce that figure before starting work.

Our e:Mission sustainability strategy sets stretching targets to reduce our environmental footprint across all areas of our work. This includes the impact of our supply chain; suppliers, materials we use and the work we do to help reduce the risk of flooding.

Construction is the single largest contributing category to our total supply chain impact. Suppliers in the construction sector contribute to 49% of our total supply chain environmental damage footprint.

We can reduce our carbon by actively seeking and innovating low carbon solutions for our FCRM capital works. This means low carbon designs as well as low carbon materials. Sustainable designs will ultimately mean less carbon produced throughout the entire life of the scheme and protect them from future climate related vulnerabilities such as escalating raw material prices. It's only by using tools like this and working together with others in the supply chain that we will be able to meet these challenging targets.

Eric e:Mission carbon planning tool

The two components of the carbon planning tool are:

Carbon life modelling tool

- Top down whole life carbon assessment and optioneering
- Used during the project appraisal
- Enables quick and simple carbon assessment to inform the solution selection process

Carbon calculator

- Bottom up whole life carbon assessment
- Based on the preferred/implemented option
- Detailed assessments, incrementally built up during the delivery phase
- Final carbon calculators create data points in model

CONSTRUCTION CARBON Reduce embodied carbon by 40%

Operational instruction

Operational instruction: Whole life (construction) carbon planning tool (Word, 228KB)

Case studies and factsheets

We have compiled a set of case studies and factsheets to help you on your low carbon journey and achieve your best low carbon solution. If you would like to share your carbon journey, please complete the case study template and send it to carbonplanningtool@environment-agency.gov.uk

Low carbon case studies (asite)

Low carbon fact sheets (asite)

Low carbon case study template (Word, 725KB)

Page tools

Email

Print

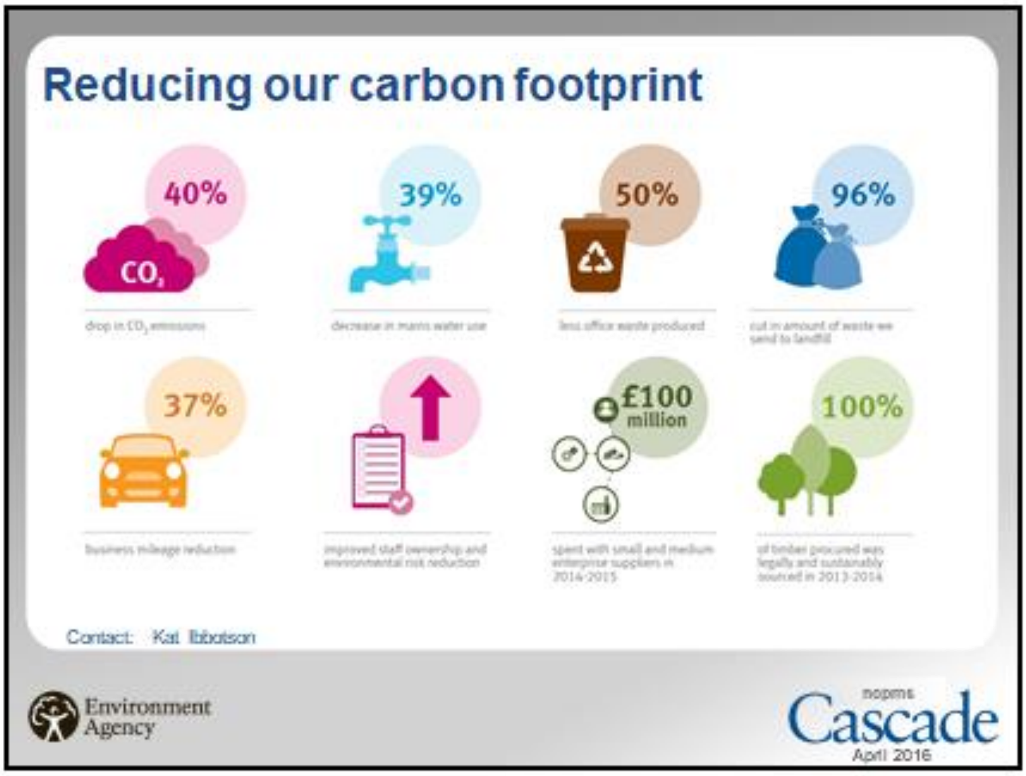
Feedback

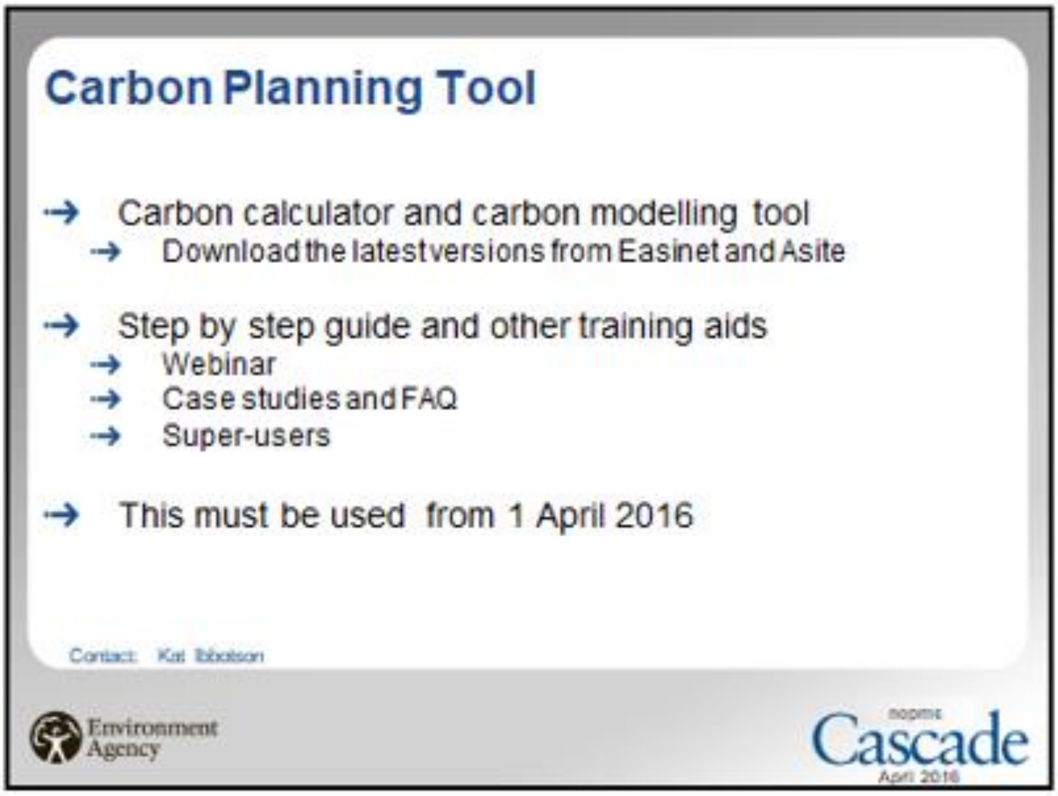
Appendix E communications and Reports 2016 – 2020

- Current Magazine Edition 9 - **https://en.calameo.com:%20https:/en.calameo.com/read/00443368011ee2c6f0cbb**
- Current Magazine Edition 11 - **https://environment-agency.uk.com/3O4M-FDUR-1EVASF-A6PZ6-1/c.aspx**
- Current Magazine Edition 12 - **https://environment-agency.uk.com/3O4M-HICW-1EVARP-BZNMS-1/c.aspx**

Appendix E communications and Reports 2016 – 2020

Cascade Slides





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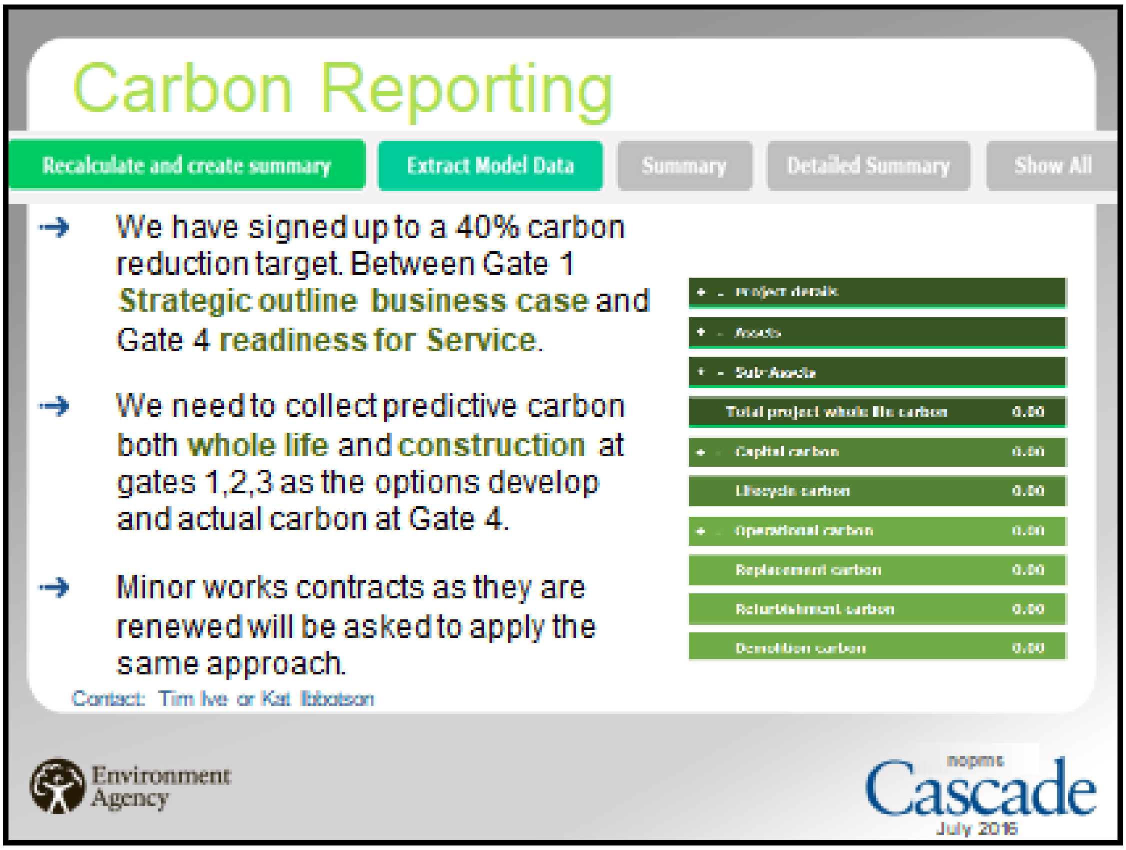

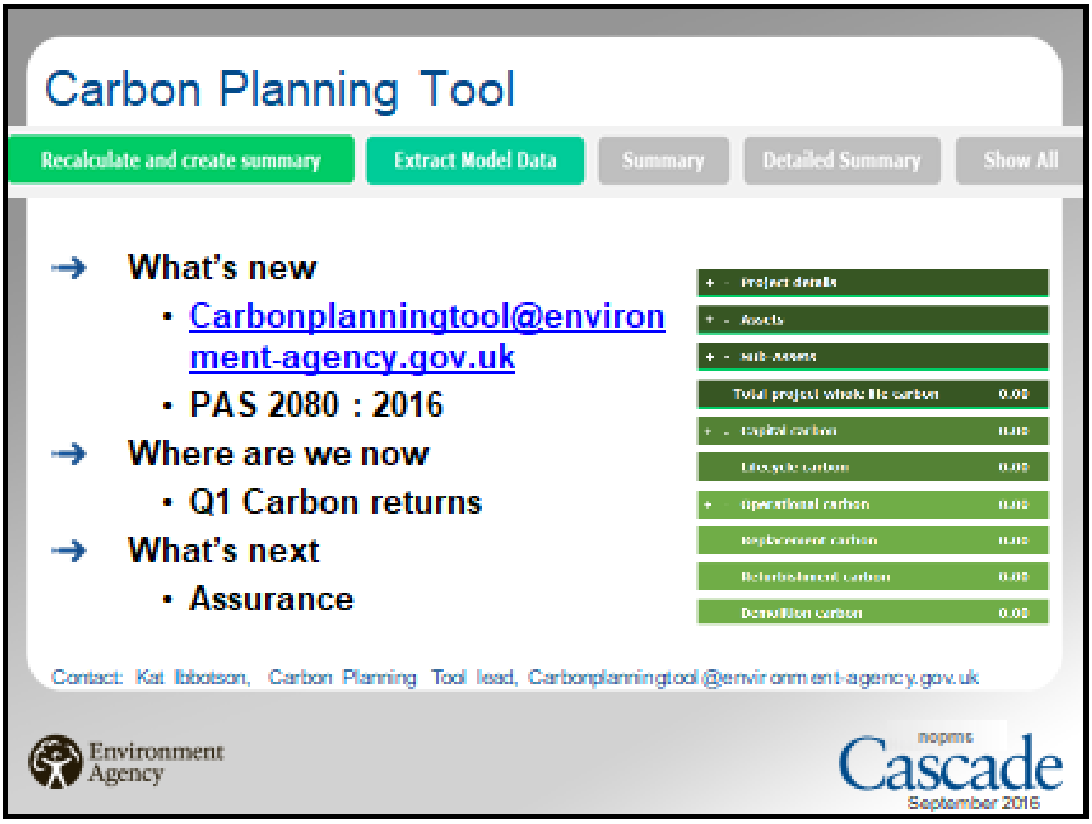

Appendix E communications and Reports 2016 – 2020

Promotional presentations Flood and Coast 2019

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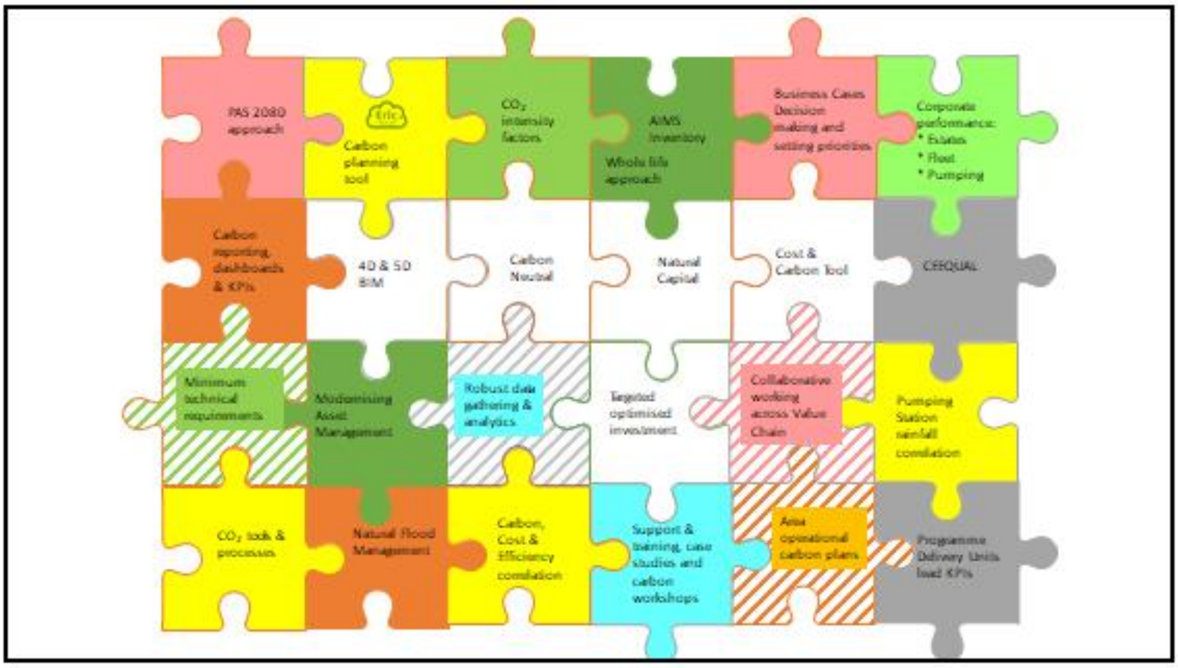
Appendix E communications and Reports 2016 – 2020



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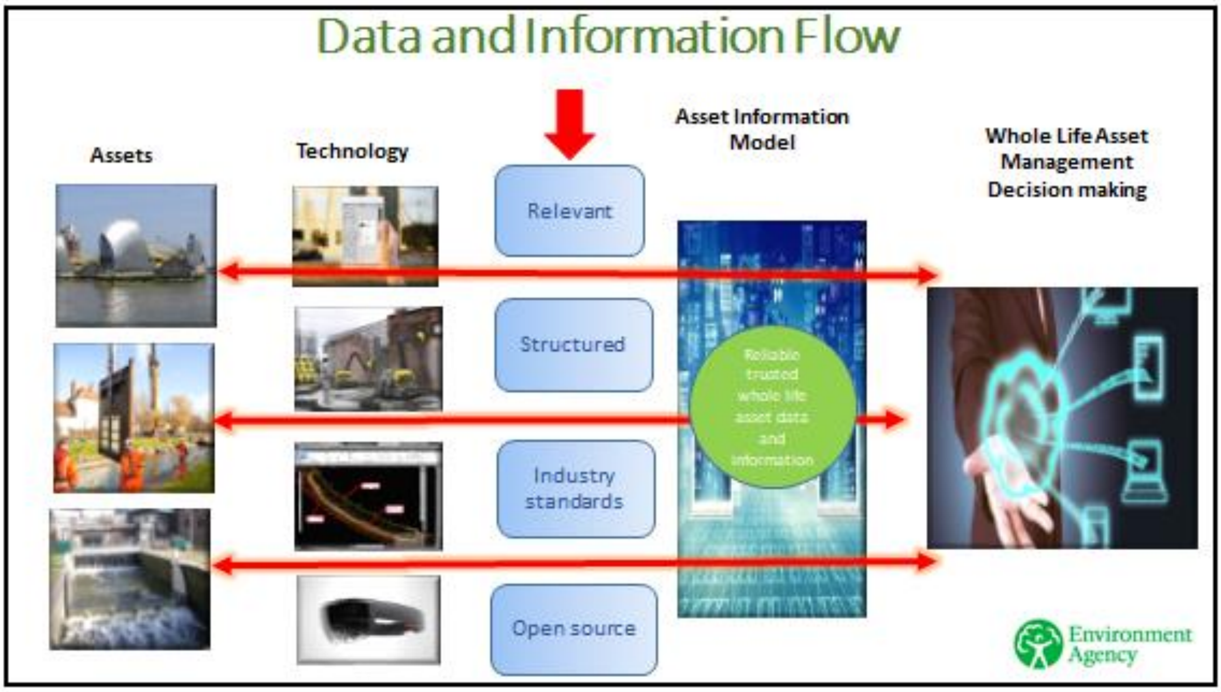

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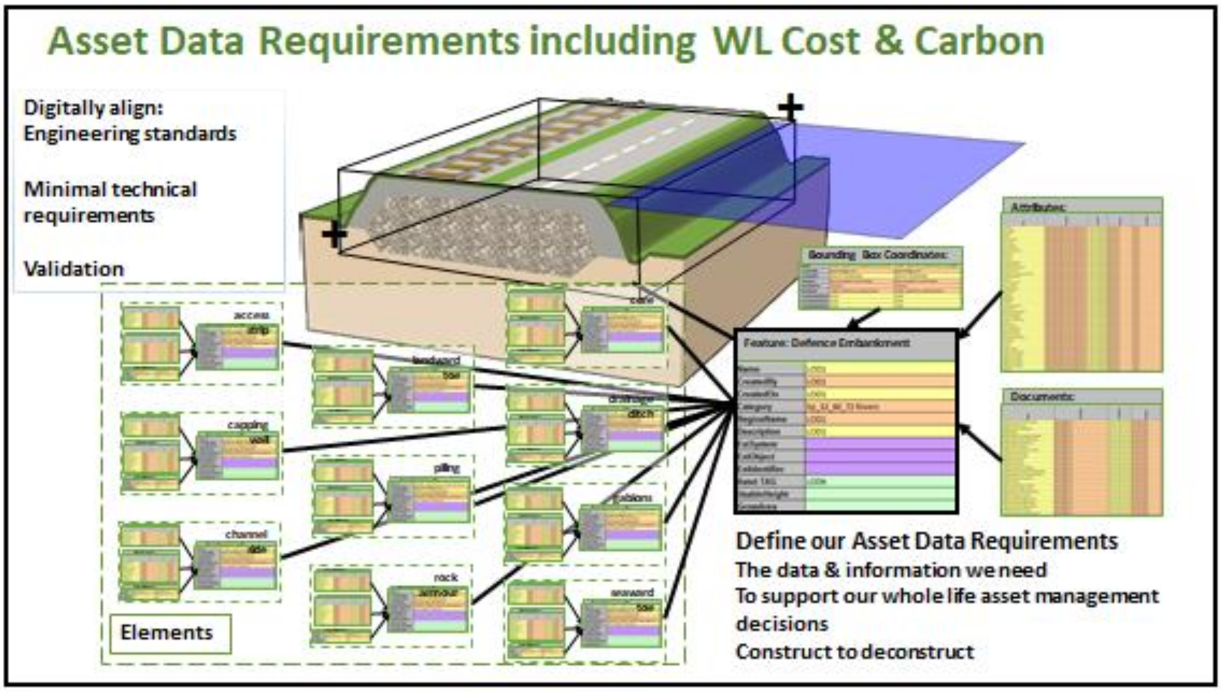

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Appendix E communications and Reports 2016 – 2020

Carbon and Cost Journey

- Cost and carbon – 1 action 2 outputs
- Whole life – inclusive of carbon sequestration and offsetting
- Digital – BIM journey, machine readable, enables automation
- Data sources - industry standards, ICE database
- Asset data requirements – construct to deconstruct, circular economy
- Access to Eric visit www.gov.uk or email carbonplanningtool@environment-agency.gov.uk

Environment Agency

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Appendix E communications and Reports 2016 – 2020

Flood and Coast Expo Low Carbon Challenge 2016

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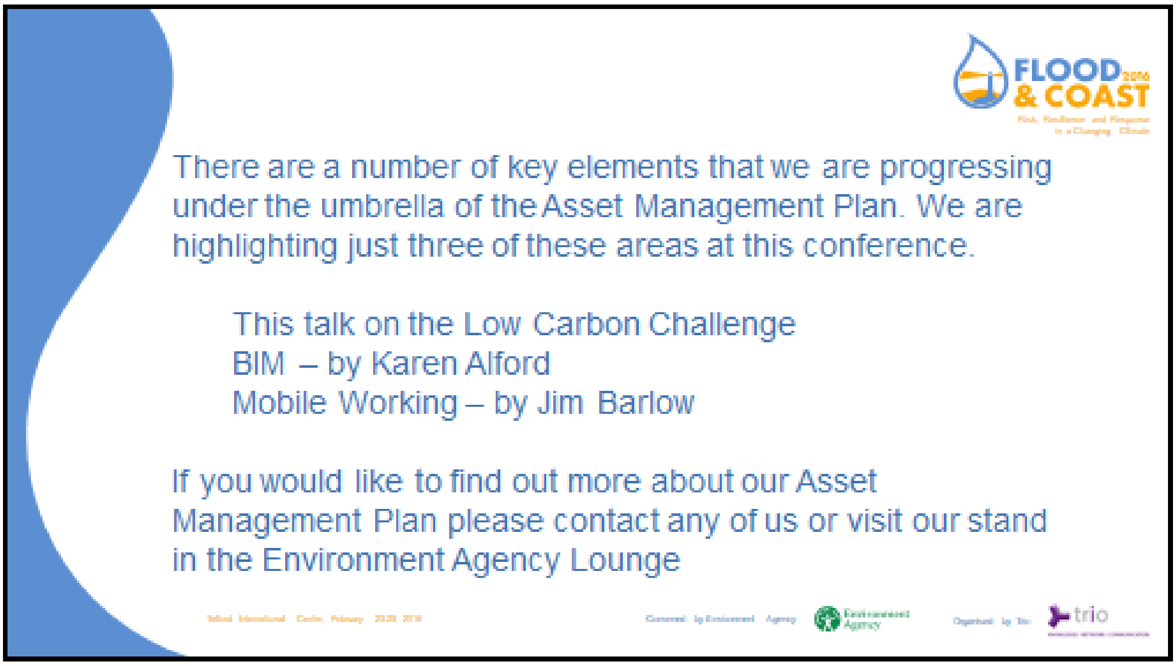

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Appendix E communications and Reports 2016 – 2020

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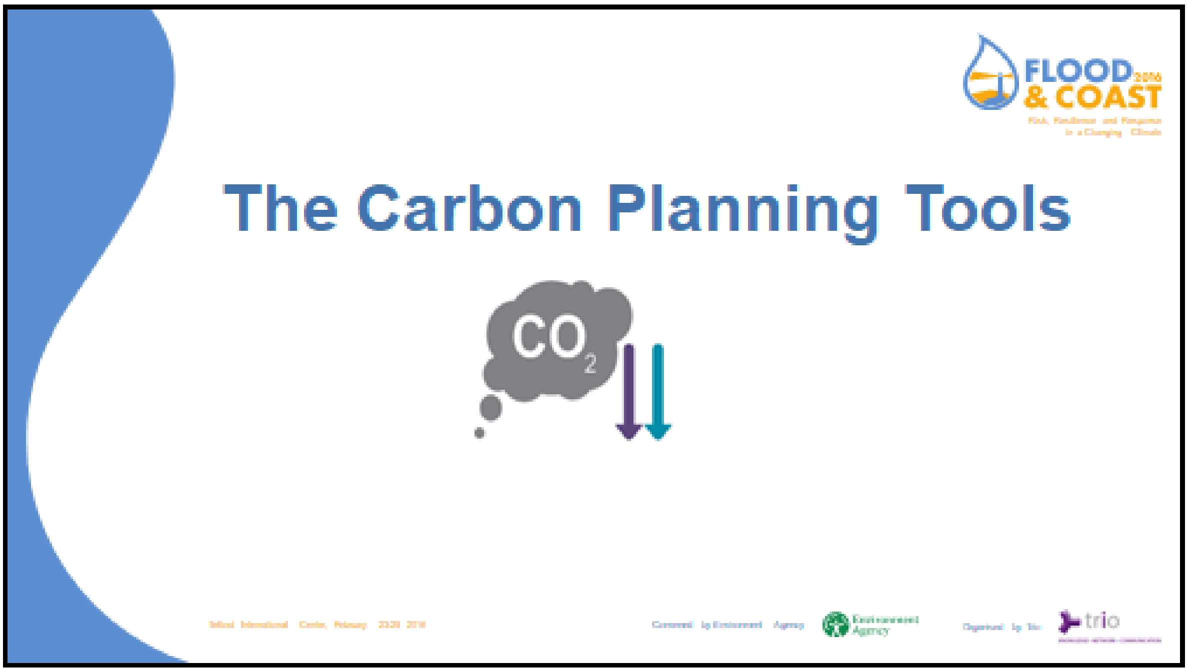
FLOOD 2016
& COAST
The Carbon Planning Tools
CO2
trio

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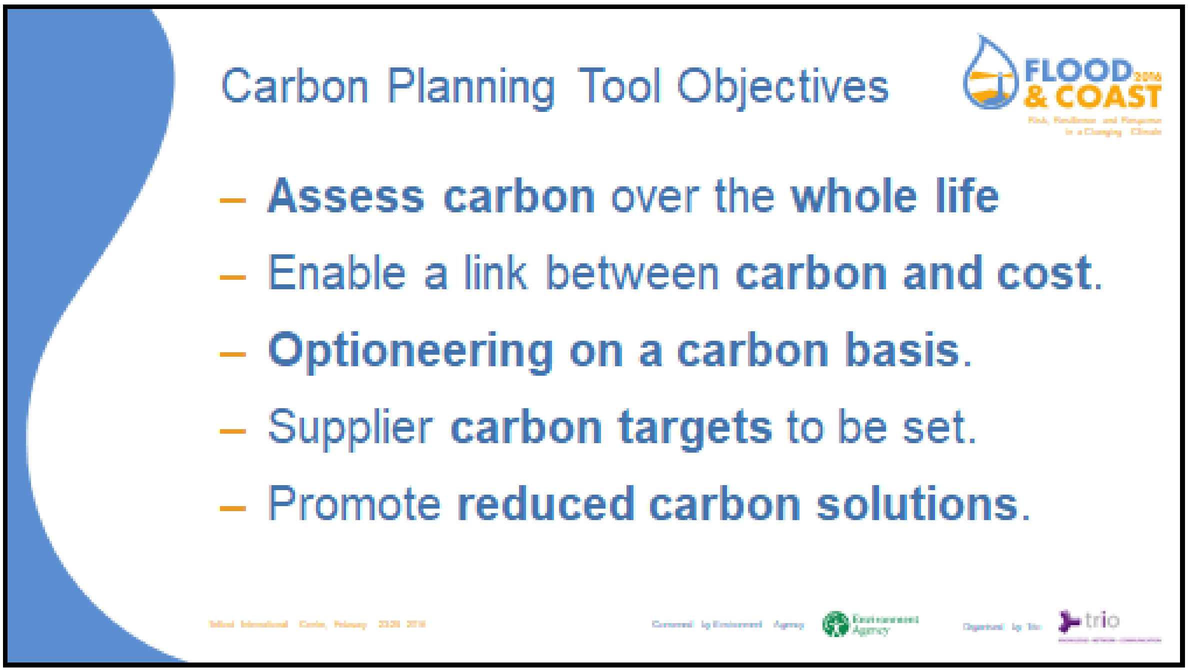
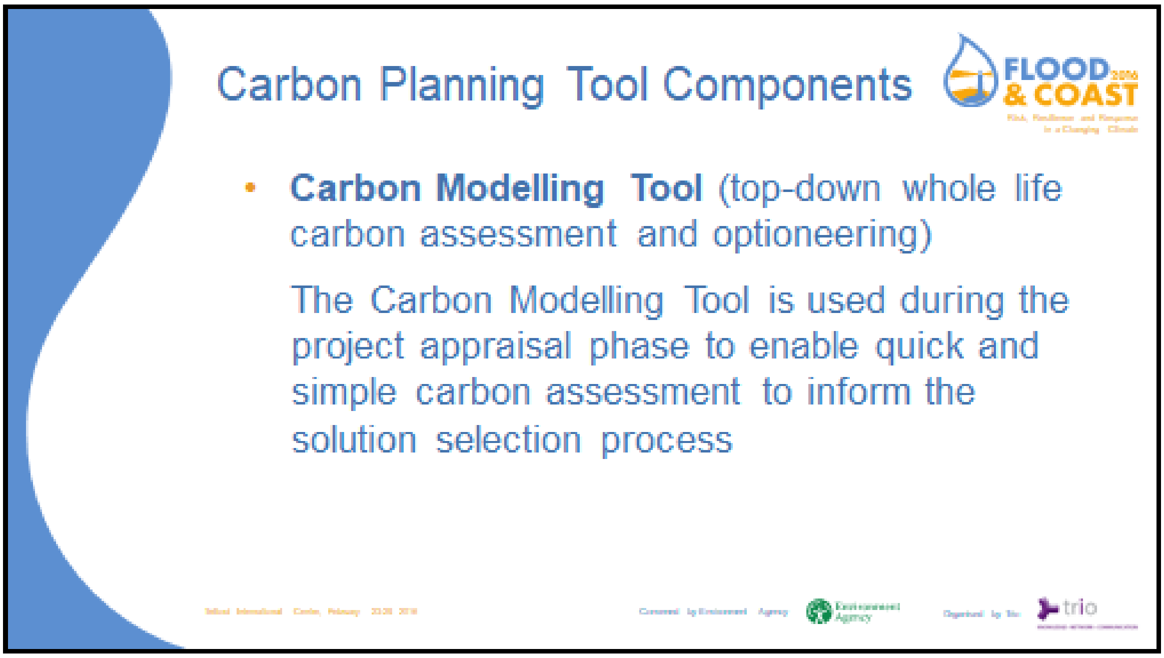
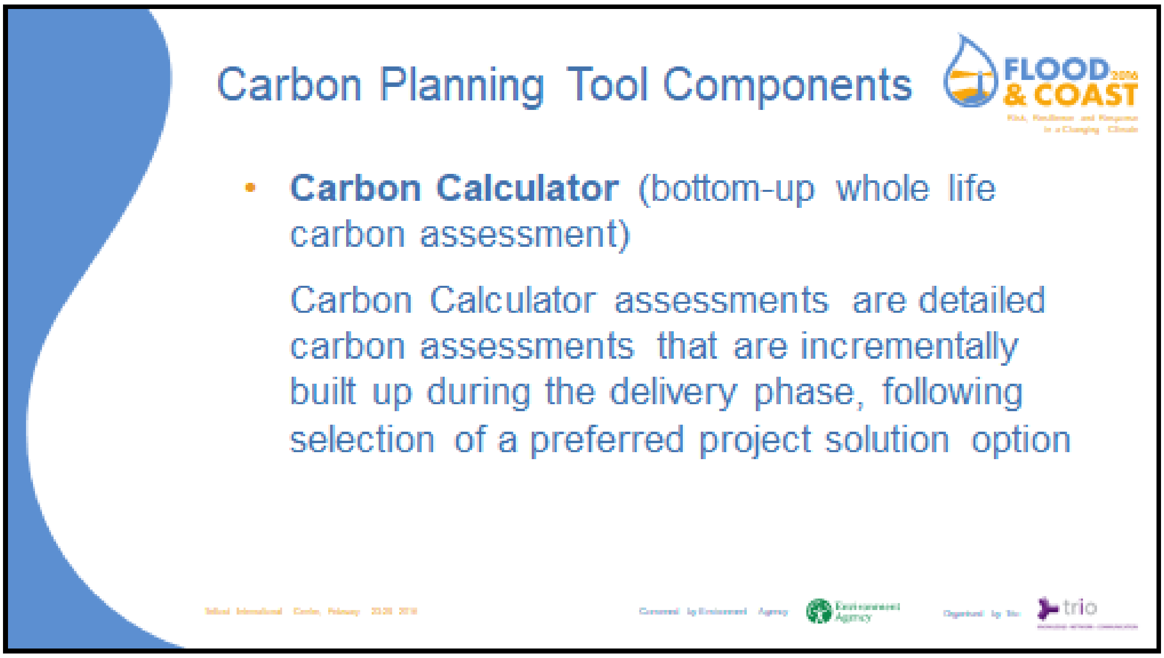

Carbon Planning Tool Objectives
FLOOD 2016
& COAST
– Assess carbon over the whole life
– Enable a link between carbon and cost.
– Optioneering on a carbon basis.
– Supplier carbon targets to be set.
– Promote reduced carbon solutions.
trio

8


Carbon Planning Tool Components
FLOOD 2016 & COAST
• **Carbon Modelling Tool** (top-down whole life carbon assessment and optioneering)
The Carbon Modelling Tool is used during the project appraisal phase to enable quick and simple carbon assessment to inform the solution selection process
trio

9


Carbon Planning Tool Components
FLOOD 2016 & COAST
• **Carbon Calculator** (bottom-up whole life carbon assessment)
Carbon Calculator assessments are detailed carbon assessments that are incrementally built up during the delivery phase, following selection of a preferred project solution option
trio

10

Appendix E communications and Reports 2016 – 2020

Eric Supply chain Conference,

Presented by K Ibbotson – environment agency and F Moore Land and Water

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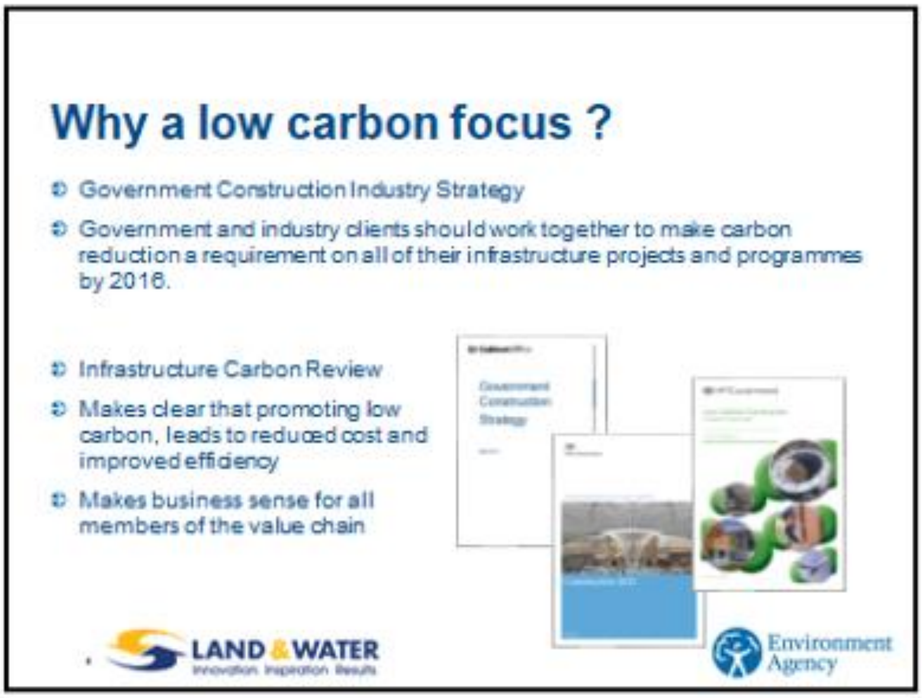

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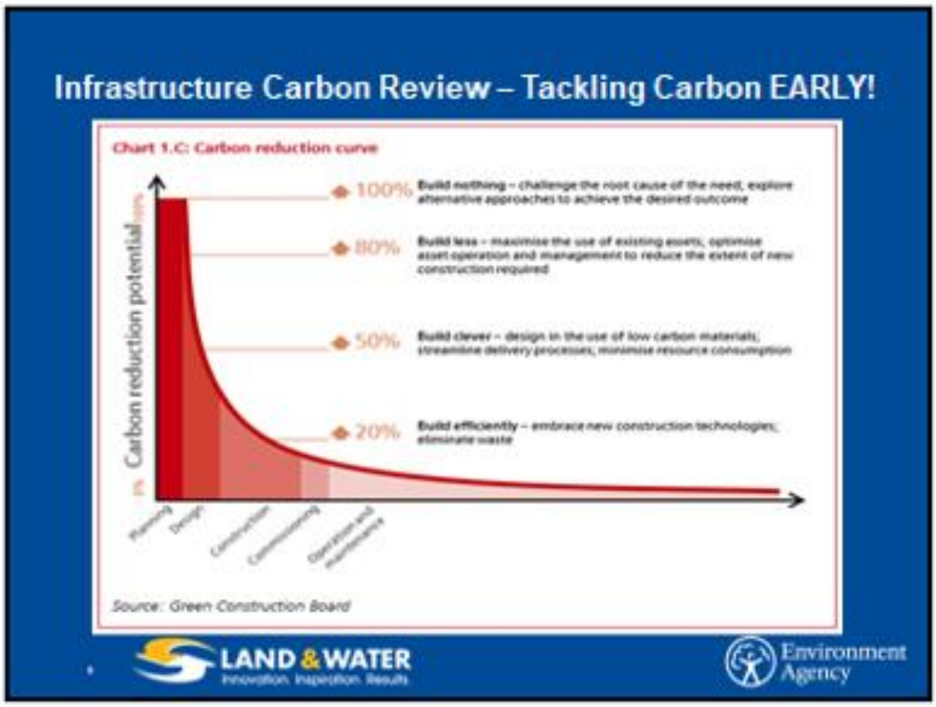

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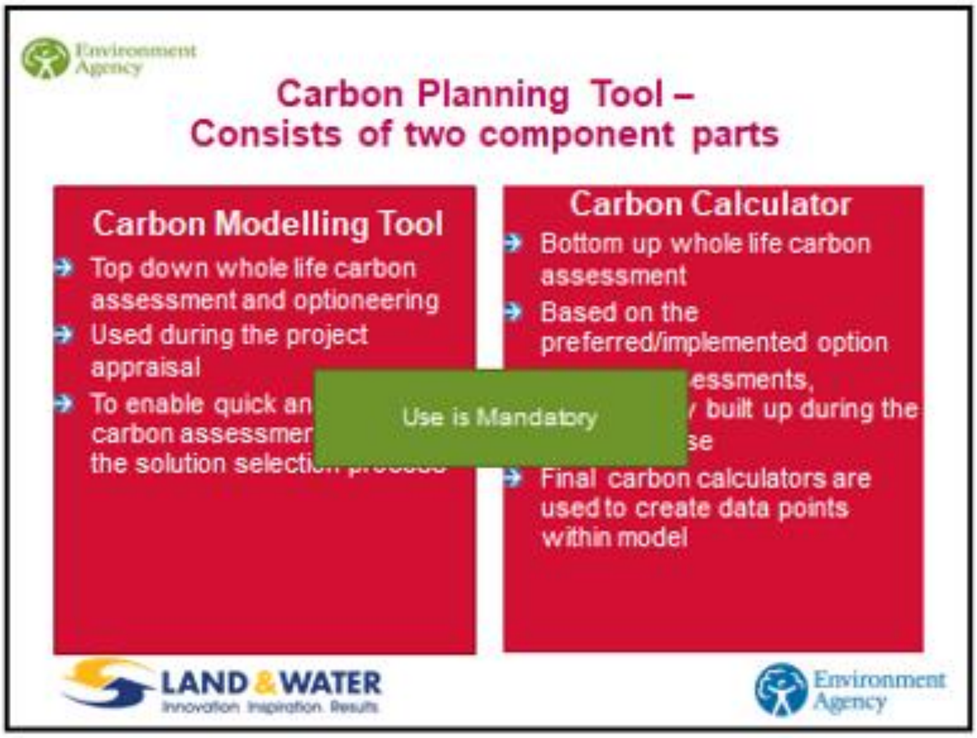

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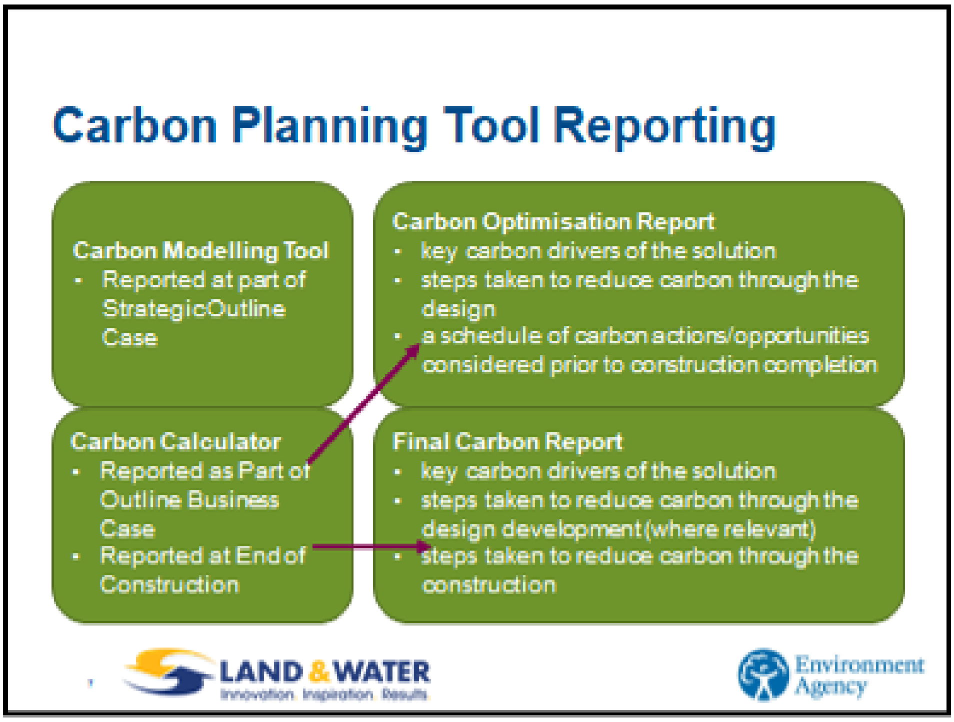

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Appendix E communications and Reports 2016 – 2020

8

Questions

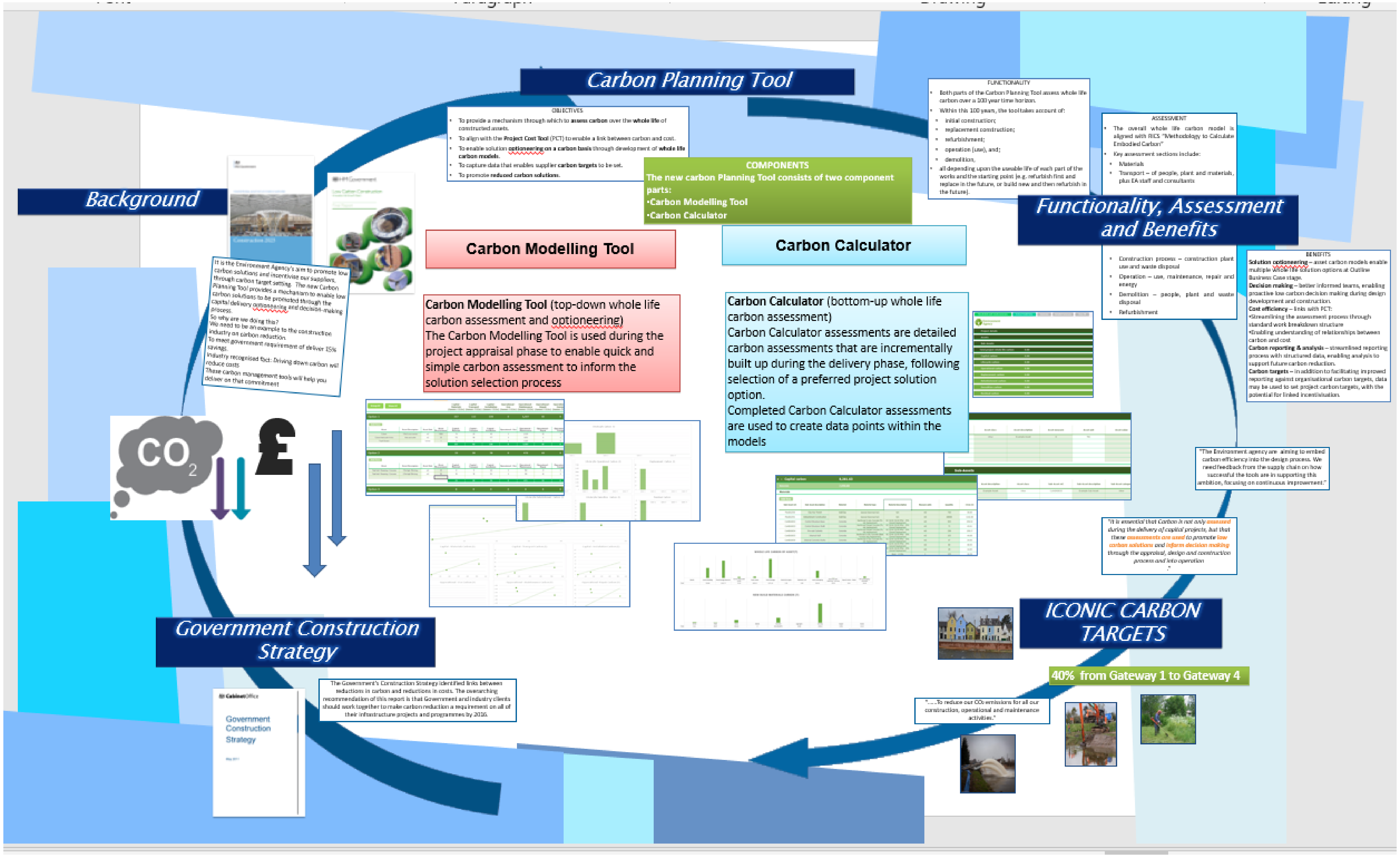
1. What opportunities exist within the EA supply chain to reduce carbon?
2. What prevents those opportunities being realised?
3. How can suppliers best assist in realising the EA targets?
4. In 5/10 years how will we be tackling carbon reduction differently?
5. What are you currently doing in your organisation to actively reduce carbon?

LAND & WATER
Innovation Inspiration Results

Environment Agency

9

Appendix E communications and Reports 2016 – 2020



APPENDIX F Eric Whole Life Carbon Planning Tool

- .gov.uk external - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/571707/LIT_7067.pdf
- Eric Whole Life Carbon Planning Tool – access via carbonplanningtool@environment-agency.gov.uk
    - Carbon Modelling Tool (EA, 2020c);
    - Carbon Calculator (EA, 2020d);
    - CPT Operational Instruction (EA, 2020e);

APPENDIX G Eric WLCPT training and supporting documentation

- E-Learning link - https://ericenvironmentagency.co.uk/;
- Eric Whole Life Carbon Planning Tool – access to case studies and factsheets via carbonplanningtool@environment-agency.gov.uk;
- Produced as part of the low carbon future programme by Mott MacDonald and via individual project teams:
    - sprayed concrete;
    - cemfree concrete;
    - vacuum excavation;
    - trench mix;
    - hydrogen power lights;
    - geosynthetic clay liners;
    - precast wall;
    - wall injection;
    - polyurethane resin;
    - pneumatic actuated gates;
    - plastic piles;
    - pumping station reduced operational carbon;
    - clay import;
    - Natural Flood Management (EA, 2019f);
        - methodology factsheet;
        - Sussex flow case study;
        - Holniote case study;
        - Tebay case study;
    - limpet dam;
    - brico block;
    - hydroslide;
    - concrete canvas;
    - AACM;
    - cathodic protection.

- https://dbgholdings.com/wp-content/uploads/2018/10/Environment-Agency-Foulton-Hall.pdf
- Eric e-learning https://ericenvironmentagency.co.uk/.

APPENDIX H Action Research VAR data

	A	B	C	D	E	F
91		Correlation				
92	VAR 7 & 8 (25 projects)	-0.13	VAR 8 & 9 (full list)	0.15	VAR 9 & 10 (full list)	0.09
93	VAR 7 & 9 (25 projects)	0.18	VAR 8 & 9 (25 projects)	0.40	VAR 9 & 10 (25 projects)	0.03
94	VAR 7 & 10 (25 projects)	0.09	VAR 8 & 10 (full list)	0.17	VAR 9 & 11	
95	VAR 7 & 11 (25 projects)		VAR 8 & 10 (25 projects)	0.20		
96			VAR 8 & 11			
97		P - Value				
98	VAR 7 & 8 (25 projects)	0.20	VAR 8 & 9 (full list)	0.20	VAR 9 & 10 (full list)	0.20
99	VAR 7 & 9 (25 projects)	0.10	VAR 8 & 9 (25 projects)	**0.00**	VAR 9 & 10 (25 projects)	0.20
100	VAR 7 & 10 (25 projects)	0.20	VAR 8 & 10 (full list)	0.20	VAR 9 & 11	
101	VAR 7 & 11 (25 projects)		VAR 8 & 10 (25 projects)	0.10		
102			VAR 8 & 11			
103						

Appendix H Action Research VAR 7

	A	C	D	E	F	G	H	I	J	K	L	M
1		VAR 7 Cost										
3	Project number	Initial Capital Cost (£k)	Final Capital Cost (£k)	Capital cost change	0 = 50% or above increase, 1 = 50% or below increase, 2 = 50% or below decrease, 3 = 50% or above decrease	%	Gateway 4 final Capital Carbon	Carbon cost Average	Capitla carbon metric 5.28 tCO_2 per £10k capital spend	%	All Total	%
4								Column H/Column D	0 = Above average, 1 = Below Average			
5	Project 3	10.00	392.00	-382.00	0.00	0.00	3163.00	8.07	1.00	100.00	1.00	25.00
6	Project 9	10.00	319.00	-309.00	0.00	0.00	34.00	0.11	1.00	100.00	1.00	25.00
7	Project 10	10.00	627.00	-617.00	0.00	0.00	240.00	0.38	1.00	100.00	1.00	25.00
8	Project 11	79.30	538.00	-458.70	0.00	0.00	93.39	0.17	1.00	100.00	1.00	25.00
9	Project 12	141.50	843.00	-701.50	0.00	0.00	161.65	0.19	1.00	100.00	1.00	25.00
10	Project 13	605.90	5296.00	-4690.10	0.00	0.00	182.00	0.03	1.00	100.00	1.00	25.00
11	Project 14	10.00	474.00	-464.00	0.00	0.00	91.68	0.19	1.00	100.00	1.00	25.00
12	Project 15	77.90	423.00	-345.10	0.00	0.00	426.11	1.01	1.00	100.00	1.00	25.00
13	Project 16	952.00	5081.00	-4129.00	0.00	0.00	1714.18	0.34	1.00	100.00	1.00	25.00
14	Project 19	41.50	20.20	21.30	3.00	100.00	12.32	0.61	1.00	100.00	4.00	100.00
15	Project 20	950.00	342.00	608.00	3.00	100.00	2291.88	6.70	0.00	0.00	3.00	75.00
16	Project 29	29.67	1336.00	-1306.33	0.00	0.00	394.16	0.30	1.00	100.00	1.00	25.00
17	Project 32	10.00	3541.00	-3531.00	0.00	0.00	724.00	0.20	1.00	100.00	1.00	25.00
18	Project 33	10.00	15.70	-5.70	0.00	0.00	31.78	2.02	1.00	100.00	1.00	25.00
19	Project 34	10.00	108.00	-98.00	0.00	0.00	29.00	0.27	1.00	100.00	1.00	25.00
20	Project 38	2839.00	25792.00	-22953.00	0.00	0.00	42422.74	1.64	1.00	100.00	1.00	25.00
21	Project 42	653.80	3393.00	-2739.20	0.00	0.00	5059.00	1.49	1.00	100.00	1.00	25.00
22	Project 43	811.00	385.00	426.00	3.00	100.00	6167.00	16.02	0.00	0.00	3.00	75.00
23	Project 53	10.00	484.00	-474.00	0.00	0.00	244.53	0.51	1.00	100.00	1.00	25.00
24	Project 54	10.00	191.00	-181.00	0.00	0.00	332.29	1.74	1.00	100.00	1.00	25.00
25	Project 62	10.00	22.62	-12.62	3.00	100.00	236.07	10.44	0.00	0.00	3.00	75.00
26	Project 63	10.00	22.12	-12.12	3.00	100.00	281.96	12.75	0.00	0.00	3.00	75.00
27	Project 69	101.90	751.00	-649.10	0.00	0.00	469.00	0.62	1.00	100.00	1.00	25.00
28	Project 70	10.00	1352.00	-1342.00	0.00	0.00	270.60	0.20	1.00	100.00	1.00	25.00
29	Project 71	10.00	2862.00	-2852.00	0.00	0.00	485.40	0.17	1.00	100.00	1.00	25.00
30	Count	25.00	25.00	25.00	Total		25.00	25.00	25.00	Total	Total	
31	Sum	7413.47	54610.64	-47197.17			65557.74	66.18	21.00			
32	Mean	296.54	2184.43	-1887.89	0.60	20.00	2622.31	2.65	0.84	84.00	1.44	36.00
33	Percentage	1186.15	8737.70	-7551.55	**20.00**	80.00	10489.24	10.59	**84.00**	8400.00	**36.00**	900.00
34					Column F				Column J			
35					Countif 0				Countif 0			
36					20.00				4.00			
37					Countif 1				Countif 1			
38					0.00				21.00			
39					Countif 2							
40					0.00							
41					Countif 3							
42					5.00							
43												

Appendix H Action Research VAR 8 (82 projects)

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	VAR 8 tonne of carbon																
2	Project number	Gateway 1 Actual Date	Gateway 4 Actual Date	Gateway 1 - Carbon Modelling tool -Capital carbon (t)	Gateway 4 - Carbon Calculator tool -Capital carbon (t)	Carbon reduction (if minus) at Gateway 4 (t)	Capital carbon budget	Reduction required against Capital Carbon budget	% change against organisations 40% capital reduction target	Reduction in CO_2 from Carbon Budget	Total	Reduction required against CMT	% change against organisations 40% capital reduction target	Reduction in CO_2 from CMT	Total	All Total	%
3										<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6				<0 = 0, 0 = 1, 1-10 = 2, 10-20 = 3, 20-30 = 4, 30-40 = 5, > 40 = 6			
4	Project 1	16/10/2006	16/11/2018	535.00	2,440.54	1,905.54	1,742.40	1,045.44	182.27%	0	0	321.00	593.63%	0	0	0	0
5	Project 2	13/11/2008	14/12/2018	4,168.00	434.00	- 3,734.00	1,636.80	982.08	-380.21%	6	100	2,500.80	-149.31%	6	100	12	100
6	Project 3	01/05/2012	02/10/2017	8,725.00	3,163.00	- 5,562.00	-	-	0.00%	0	0	5,235.00	-106.25%	6	100	6	50
83	Project 80	15/05/2018	28/09/2020	5,219.00	326.19	- 4,892.81	1,853.81	1,112.28	-439.89%	6	100	3,131.40	-156.25%	6	100	12	100
84	Project 81	15/06/2018	27/09/2019	9.32	119.70	110.38	366.96	220.18	50.13%	0	0	5.59	1973.89%	0	0	0	0
85	Project 82	17/10/2017	29/04/2019	595.00	80.78	- 514.22	472.03	283.22	-181.56%	6	100	357.00	-144.04%	6	100	12	100
86									Count	82.00	Total		Count	82.00	Total	All Total	
87									Sum	190.00			Sum	252.00			
88									Mean	2.32	38.62		Mean	3.07	51.22	5.39	44.92
89									Percentage	**38.62**	643.63		Percentage	**51.22**	853.66	**44.92**	374.32
96									Countif <0 =	32			Countif <0 =	29			
97									Countif 0 =	4			Countif 0 =	5			
98									Countif 1 - 10 =	15			Countif 1 - 10 =	6			
99									Countif 10 - 20 =	6			Countif 10 - 20 =	3			
00									Countif 20-30 =	4			Countif 20-30 =	3			
01									Countif 30-40 =	4			Countif 30-40 =	2			
02									Countif > 40 =	17			Countif > 40 =	34			
03																	

Appendix H Action Research VAR 8 (25 Projects)

Project number	VAR 8 Tonnes of carbon			
	Reduction in CO_2 from Carbon Budget	Reduction in CO_2 from CMT	Total	%
	<0 - 0, 0 - 1, 1-10 - 2, 10 20 - 3, 20-30 - 4, 30-40 - 5, > 40 - 6	<0 - 0, 0 - 1, 1-10 - 2, 10 20 - 3, 20-30 - 4, 30-40 - 5, > 40 - 6		
Project 3	0.00	6.00	6.00	50.00
Project 9	0.00	0.00	0.00	0.00
Project 10	0.00	0.00	0.00	0.00
Project 11	2.00	2.00	4.00	33.33
Project 12	0.00	0.00	0.00	0.00
Project 13	0.00	0.00	0.00	0.00
Project 14	6.00	6.00	12.00	100.00
Project 15	0.00	0.00	0.00	0.00
Project 16	3.00	6.00	9.00	75.00
Project 19	2.00	6.00	8.00	66.67
Project 20	0.00	0.00	0.00	0.00
Project 29	6.00	6.00	12.00	100.00
Project 32	0.00	0.00	0.00	0.00
Project 33	2.00	2.00	4.00	33.33
Project 34	0.00	1.00	1.00	8.33
Project 38	0.00	0.00	0.00	0.00
Project 42	0.00	0.00	0.00	0.00
Project 43	0.00	0.00	0.00	0.00
Project 53	6.00	6.00	12.00	100.00
Project 54	0.00	0.00	0.00	0.00
Project 62	0.00	0.00	0.00	0.00
Project 63	0.00	0.00	0.00	0.00
Project 69	0.00	3.00	3.00	25.00
Project 70	2.00	2.00	4.00	33.33
Project 71	3.00	0.00	3.00	25.00
Count	25.00	26.00	Total	
Mean	1.28	1.84	3.12	26.00
Percentage	21.33	30.67	**26.00**	216.67

Column P		
Countiif 0	Countiif 7	Countiif 11
13.00	0.00	1.00
Countiif 1	Countiif 8	Countiif 12
1.00	0.00	3.00
Countiif 2	Countiif 8	Countiif 21
0.00	1.00	13.00
Countiif 3	Countiif 9	Countiif 22
2.00	1.00	8.00
Countif 4	Countif 10	
3.00	0.00	
Countiif 5	Countiif 11	
0.00	0.00	
Countiif 6	Countiif 12	
1.00	3.00	

Appendix H Action Research VAR 9 (82 Projects)

VAR 9 quality of implementation of a whole life carbon planning tool							
Project	Multi options reviewed in CMT	Lowest option selected in CMT	COR received	GW3 CC received	FCR received	Total	%
	0 = no, 1 = yes						
Project 1	0	0	0	0	1	1.00	20.00
Project 2	0	0	0	0	0	0.00	0.00
Project 3	0	0	0	0	0	0.00	0.00
Project 80	1	0	0	0	0	1.00	20.00
Project 81	0	0	0	0	0	0.00	0.00
Project 82	0	0	0	0	0	0.00	0.00
Count	82.00	82.00	82.00	82.00	82.00	Total	
Mean	0.23	0.04	0.16	0.10	0.07	0.60	11.95
Percentage	23.17	3.66	15.85	9.76	7.32	**11.95**	239.02
	Countif Multi options reviewed in CMT	Countif Lowest option selected in CMT	Countif COR received	Countif GW3 CC received	Countif FCR received		
	19	3	13	8	6		

Appendix H Action Research VAR 9 (25 projects)

	A	U	V
1	Project number	**VAR 9 quality of implementation of WLCPT**	
2		Total	%
4			
5	Project 3	0.00	0.00
6	Project 9	0.00	0.00
7	Project 10	0.00	0.00
8	Project 11	0.00	0.00
9	Project 12	0.00	0.00
10	Project 13	0.00	0.00
11	Project 14	13.33	40.00
12	Project 15	6.67	20.00
13	Project 16	0.00	0.00
14	Project 19	6.67	20.00
15	Project 20	6.67	13.33
16	Project 29	6.67	20.00
17	Project 32	0.00	0.00
18	Project 33	0.00	0.00
19	Project 34	6.67	20.00
20	Project 38	6.67	20.00
21	Project 42	0.00	0.00
22	Project 43	0.00	0.00
23	Project 53	0.00	0.00
24	Project 54	0.00	0.00
25	Project 62	0.00	0.00
26	Project 63	0.00	0.00
27	Project 69	0.00	0.00
28	Project 70	0.00	0.00
29	Project 71	0.00	0.00
30	Count	25.00	Total
31	Sum	53.33	
32	Mean	2.13	6.13
33	Percentage	**42.67**	122.66

Appendix H Action Research VAR 10 (82 projects)

	T	AE	AF
1		VAR 10 type of training	
2	Project	WLCPT (Eric) e-learning completed	%
3		0 = No 1 = Yes	
4	Project 1	1	100.00
5	Project 2	1	100.00
6	Project 3	1	100.00
83	Project 80	0	0.00
84	Project 81	0	0.00
85	Project 82	0	0.00
86	Count	82.00	Total
88	Mean	0.62	62.20
89	Percentage	**62.20**	6219.51
96		Countif WLCPT (Eric) e-learning completed	
97		51	
98			

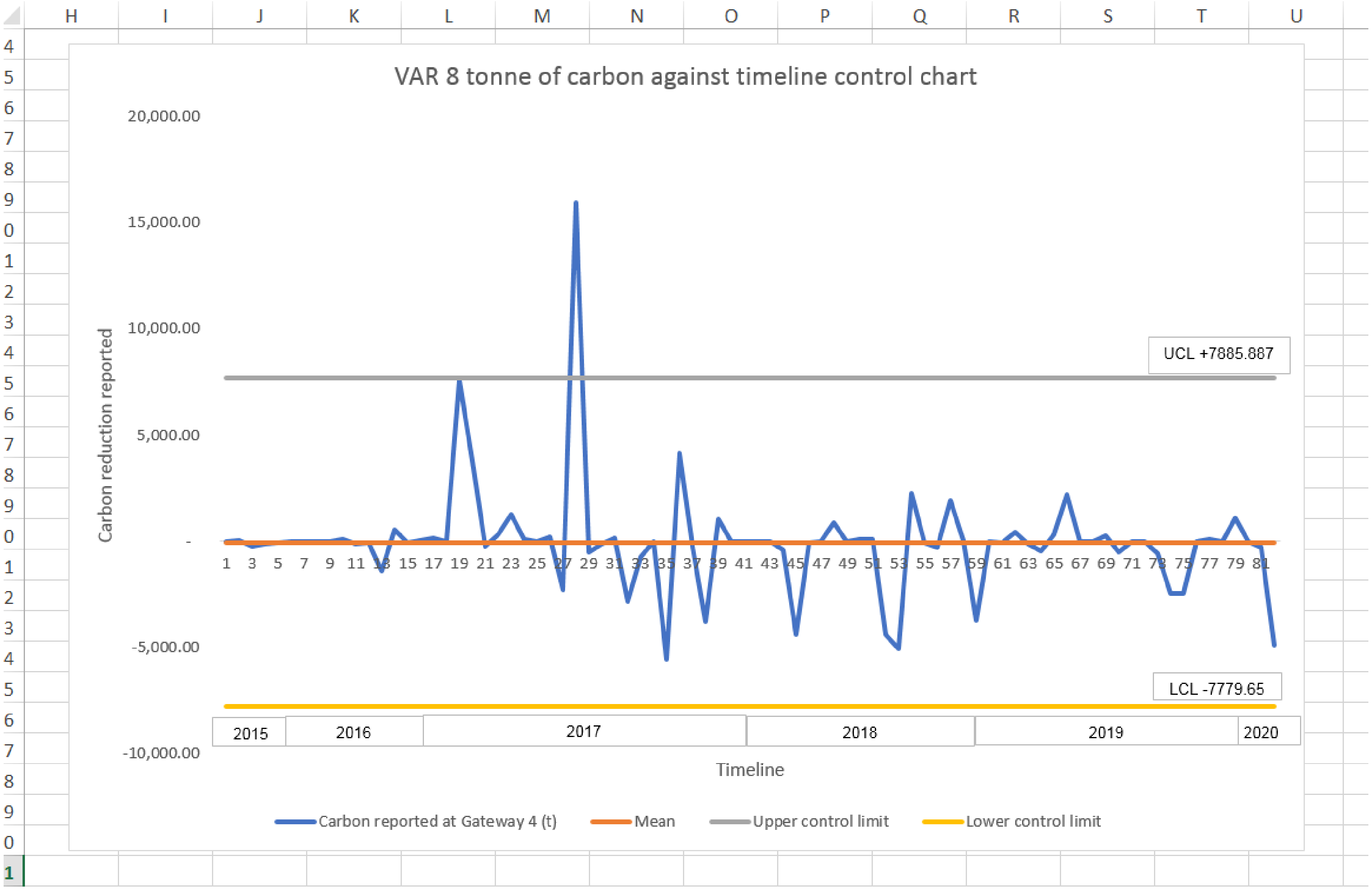
Appendix H Action Research VAR 10 (25 projects)

	AC	AD	AE	AF	AG	AH	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1	**VAR 10 type of training**															
3	Has the Eric e-Learning completed ?	%	Has Best practice learning been implemented	%	All Training Total	%	Alternative materials	Asset repair	Optimised design to inform alternative construction methods	Materials and waste management	Efficient construction	Innovative techniques	Natural flood management	No best practice identified	Total	%
4	0 = No, 1 = Yes		0 = No, 1 = Yes				0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	0 = No, 1 = Yes	1 = No		
5	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
6	0.00	0.00	1.00	100.00	1.00	50.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
7	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
9	0.00	0.00	1.00	100.00	1.00	50.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
10	0.00	0.00	1.00	100.00	1.00	50.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
11	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
12	0.00	0.00	1.00	100.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
13	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
14	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	14.29
15	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
16	1.00	100.00	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
17	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
19	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	3.00	42.86
21	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	28.57
22	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
23	1.00	100.00	1.00	100.00	2.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
24	0.00	0.00	1.00	100.00	1.00	50.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	3.00	42.86
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	14.29
26	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
28	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	14.29
29	1.00	100.00	1.00	100.00	2.00	100.00	0.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	4.00	57.14
30	25.00	Total	25.00	Total	Total		25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	Total	
31	15.00		16.00				0.00	13.00	2.00	11.00	2.00	0.00	0.00	8.00		
32	0.60	60.00	0.64	64.00	1.24	62.00	0.00	0.52	0.08	0.44	0.08	0.00	0.00	0.32	1.44	20.57
33	**60.00**	6000.00	**64.00**	6400.00	**62.00**	3100.00	0.00	52.00	8.00	44.00	8.00	0.00	0.00	32.00	**20.57**	293.88

Appendix H Action Research Control chart

	A	B	C	D	E	F
1			MEAN	-46.88		
2			STDV	2577.59		
3						
4	Graph horizontal number	Gateway 4 Actual Date	Carbon reported at Gateway 4 (t)	Mean	Upper control limit	Lower control limit
5	1	30/04/2015	13.00	-46.88	7685.887	-7779.65
6	2	31/07/2015	48.00	-46.88	7685.887	-7779.65
7	3	02/11/2015	- 210.00	-46.88	7685.887	-7779.65
3	79	31/12/2019	1,099.60	-46.88	7685.887	-7779.65
4	80	28/02/2020	- 13.19	-46.88	7685.887	-7779.65
5	81	17/04/2020	- 271.85	-46.88	7685.887	-7779.65
6	82	28/09/2020	- 4,892.81	-46.88	7685.887	-7779.65
7						
8		Count	82.00			
9		Sum	-3844.21			
0		Mean	-46.88			
1		Percentage	**-781.34**			
2		Median	-9.70			
3		Mode	0.00			
4		Minimum	1.00			
5		Maximum	6.00			
6		Range	5.00			
7		SD	2577.59			
8						

Appendix H Action Research Control chart



APPENDIX I Publications and public domain validation

Conference proceedings

- Ibbotson, K. F. (2015). Change management in public agencies to attain low carbon efficiencies. *IPGRC 2015.* Salford: Salford University;

- Ibbotson, K. F. (2017). Change Management in Public Agencies to Attain Efficiencies. *IPGRC 2017.* Salford: Salford University;

    - Achieved Dean of Research award;

- Ibbotson, K. a. (2019). How training can support low carbon prioritisation in flood and coast risk management construction. *IPGRC 2019.* Salford: Salford University;

    - Achieved Energy House Lab award.

Journal Paper

- Ibbotson, K. a. (2019). The challenges of prioritising low carbon in public sector Flood and Coastal Erosion Risk Management (FCERM) construction. *International Journal of Building Pathology* Vol 37 No. 5, pp. 615-628

Awards and Public representation of the organisation via presentations

2015

- Shortlisted for Women in Construction Green Leadership Award – WLCPT as a case study

2016

- Shortlisted for Women in Construction Green Leadership Award – WLCPT as a case study (also secured funding for event table at awards ceremony)
- Presented at Flood and Coast 2016 – subject WLCPT

2017

- Shortlisted for Women in Construction and Engineering (WICE, 2017)– Best Woman in Environment and Sustainability
- Presented at Volvo Construction Climate Challenge (CCC, 2016, CCC, 2017, CCC, 2016, CCC, 2017)– subject WLCPT (Eric)
- Shortlisted Water Industry Achievement Award 2017 – subject implementation of WLCPT

2018

- Presented at Flood and Coast 2018 – subject carbon and cost;
- Shortlisted for New Civil Engineer Tech Fest awards – WLCPT (Eric) as a case study (also secured funding for a table at the awards event);
- Judge at British Construction Industry awards – carbon category.

2019

- Nominated for EA employee awards;
- Presented at National Construction expo (Speakers Kat Ibbotson, 2019) – Cost and Carbon Tool as a topic;
- Participation in i3P consultant flagship project – case studies, factsheets and capital carbon maturity review utilised as evidence;
- Presented at the roll out of the Inventory of (embodied) carbon (ICe) database (RICS, 2019);
- Presented at Flood and Coast 2019 – subject carbon and cost (Flood and Coast, 2019); secured an event stand to promote low carbon construction solutions;
- Judge at British Construction Industry awards (NCE, 2019)– sustainability and environment category;
- Infrastructure Projects Authority – leading decarbonisation workshop;
- Panel expert – Mott MacDonald 2019 Carbon crunch;
- Women in engineering society presentation/discussion (WES, 2019) – Impact of engineering on climate change
- Presentation carbon expo, February 2019 – subject 'Where to go for carbon help and support', December 2019 – subject 'EA Low carbon journey' and event stand for WLCPT promotion.

2020

- Judge at British Construction Industry Awards - (NCE, 2020);
- Judge at NCE 100 (NCE, 2020);
- ICE COP 26 Chair of work stream 1 Measuring, sharing and benchmarking carbon impacts (ICE, 2020c);
- Key note speaker, London South Bank University, Climate, Carbon, Energy and Resources Week – 23 June 2020;

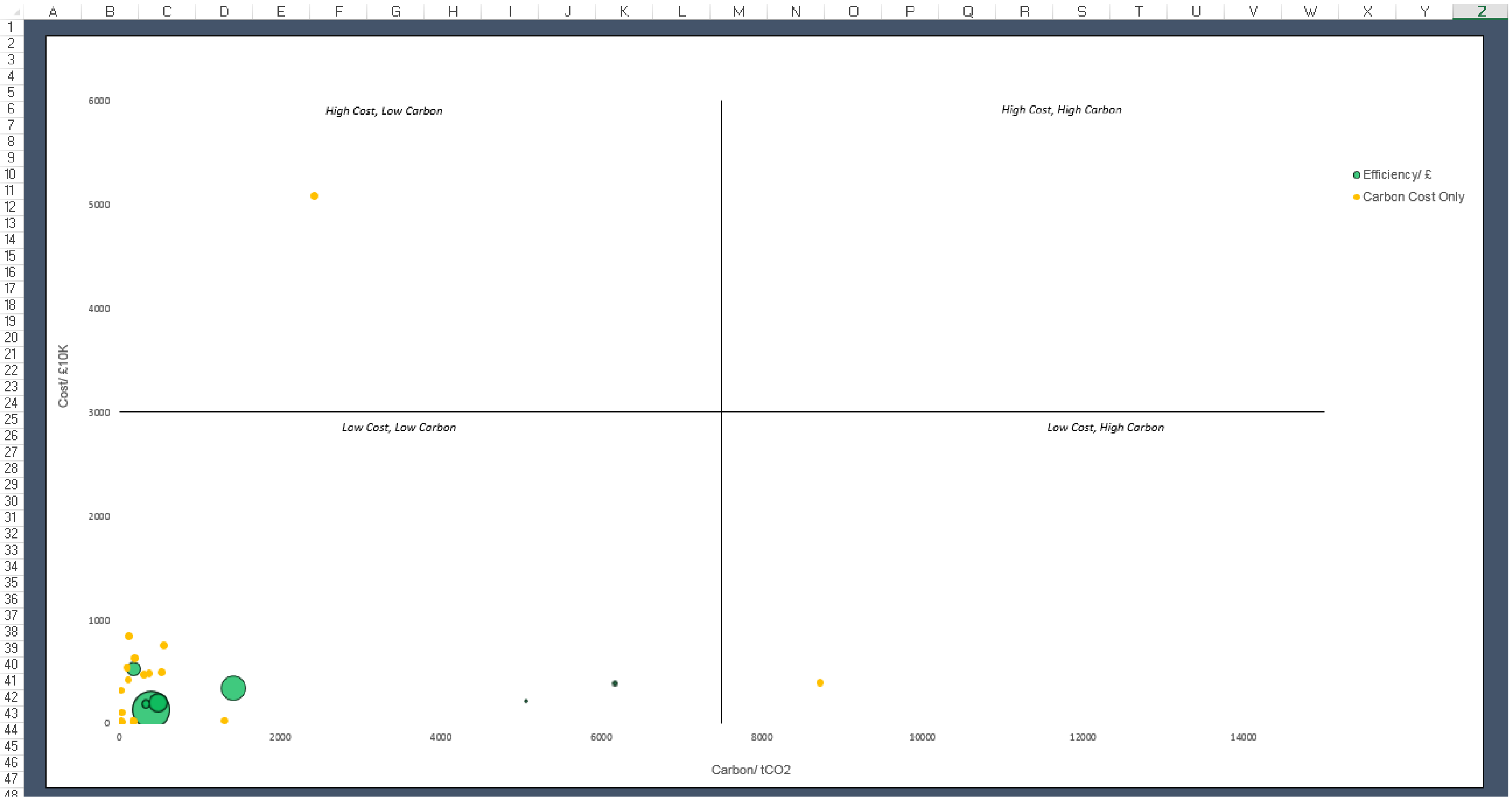
- Women in Engineering Society – Winner Top 50 Women in Engineering – Sustainability June 2020 (WES, 2020);
- Contractors Declare panel discussion (Qualis Flow, 2020);
- The cost of carbon podcast (The cost of everything, 2020).

Links to Environment Agency Eric whole life carbon planning tool and wider endorsement

- https://www.gov.uk/government/organisations/environment-agency/about/procurement
- http://teamvanoord.com/news/eric-helps-tvo-cut-carbon/
- https://www.iema.net/event-reports/2017/03/29/quantifying-the-impact-of-the-supply-chain-the-environment-agency-approach/
- https://cdn.naturalresources.wales/media/685956/case-study-1-carbon-planning-tool.pdf

APPENDIX J Low carbon future programme

Cost Carbon and Efficiency Correlation (As of March 2020)



APPENDIX K Feedback for reflection

Please provide your response on whether the implementation of Eric Whole life carbon planning tool has supported the prioritisation of low carbon in Flood Coast Risk Management (FCRM)	Please provide your response on whether the wider promotion of Eric and supportive training has contributed to an organisational culture change in EA and its supply chain in the context of carbon reduction in FCRM	Please provide your response on whether author in the role of Carbon Planning Manager has successfully supported the prioritisation and promotion of low carbon in FCRM and wider industry	Name and title
I think ERIC helps people to think about alternative lower Carbon solutions compared to what they had previously planned, so it helps them swap a hard-engineered solution to a slightly lower Carbon version of that hard solution. I think what it doesn't do (which is not a failing of the tool) is to think properly at the outset of a project what are all the potential options available to me to reduce the risk of flooding at X community. We (the EA and our consultants) do not think about the sources and pathways of flooding across the whole catchments and then develop the lowest Carbon solutions to address these. We instead think of how we address a flooding problem at its receptor and this often involves, things like walls and embankments which require the emission of Carbon to construct and maintain them. So, taking a catchment-based approach in FCRM and undertaking genuine options appraisal which properly considers no Carbon and low Carbon measures is needed. Then thinking about how we offset our 'un-avoided Carbon' via schemes which sequester Carbon is the next	Having spent some time in National Ops last year I think NCPMS and NEAS know way more about this than the rest of FCRM (e.g. PSO, Asset Management and HO FCRM). So, I think it's starting to change the culture in National Ops but across FCRM we are lagging behind. This is reflected in the fact that it was not included in the first draft of our National FCRM Strategy, and in HO FCRM the number of people working on Carbon is low. Once Emission 2030 is published, I suspect there will be a rush to get up to speed. Cultural change needs to start at the top. If we genuinely want to change the projects we deliver, then Area FCRM Managers and Area Asset Managers need to ask/demand this as the area client, and challenge schemes which seem to be defaulting to hard solutions. To achieve this could it not be as simple as James Bevan making this part of his Area Directors IPPs?	I think you do a great job in creating the tools and training needed by those who manage Capital projects to help them and their consultants deliver Low Carbon solutions. However, for it to be mainstream and embedded in our culture it cannot just rely on your, your knowledge and skills that's way too much for one person. I think once Emission 2030 is published there will be a sudden upsurge in interest in this topic, especially across FCRM and I wonder if there is enough resource in place to help support a large number of staff who will have a low level of understanding of this topic?	L BG, Principal Scientist, Flood Risk Management Research Team, Environment Agency
Partly. The mandatory use of the tool has ensured that carbon must be a discussion within every business case. The tool alone cannot ensure carbon is prioritised within projects as this is the role of the appraisal guidance. The outputs from the tool have provided evidence to leadership that the carbon issue needs to be prioritised.	Partly yes it has, but common feedback has been that the tool is 'process' and culture can't be changed by 'process' alone. The campaign has raised awareness and everyone knows who Eric is and what it's for	Kat is very passionate and dedicated to carbon reduction.	Blank
The carbon planning tool Eric has unlocked the opportunity to make informed decisions, allowing our delivery teams to change the way we design, operate and maintain our assets, in a way that will reduce CO_2 emissions and save money. Delivery teams working on the creation of new assets are now considering the impact of their choices on cost and carbon. Approval has been given to run a pilot study setting carbon as the critical success criteria for the business case and investment decision for the pilot projects, to allow us to understand better the ramifications of our choices. Persevering with the business change programme over the last there years has been worthwhile as it has created a strong foundation from which to build our response to the Climate Change Challenge. It has also helped us with our journey to maturity for PAS2080.	The implementation and embedding of the new ways of working has taken a number of years. Communication with affected parties and stakeholders has reached its audiences over a variety of channels agreed and set out as part of the Communication and Engagement Plan. A comprehensive approach to providing training has been set in place. These comprise interactive training sessions, workshops, conferences, e-learning modules and formal presentations. The creation of a library of case studies is also helping to share knowledge across the supply chain and employees alike. Assurance around the reporting from projects across the £2.3bn capital investment programme has helped to improve the quality and rate of reporting against agreed carbon reduction targets. There is evidence that the carbon management process is starting to gain real traction, with a number of key successes that demonstrate the art of the possible. These successful showcase projects are now beginning to share their approach thus helping to influence the wider group. We still have some way to go however to achieve our ambitious targets.	Kat is a force for change in the civil engineering industry. She is one of few women leading a powerful change in culture and behaviour. She is making multi-million-pound savings in the public sector by cutting carbon. At the Environment Agency she is combating climate change by changing the way we are managing our flood defences. Kat has led on: • the creation of new carbon management tools • rolled out a comprehensive training programme and • has driven the implementation of an organisational wide change programme Through her vision Kat is influencing not just the Environment Agency but other asset management organisations too, as people seek to benefit from the new carbon planning tools that she has introduced. She is a regular speaker at industry events and Kat and the carbon planning tool have been short listed for a number of industry awards.	SS, National Programme Manager for Asset Management; Sustainability Lead for Flood & Coast - Environment Agency

Without Eric, carbon conversations especially around targets and measures would not have started. Eric is helping to make carbon more tangible and more 'real' to people. Our organisation is very data driven therefore the whole life carbon planning tool has helped to identify the challenges ahead - both in terms of emissions and low carbon ways of working.	I believe Eric and the training has and still is contributing to EA organisational culture change. There is a long and challenging journey ahead but Eric is providing us with the intelligence of where we are at and where we need to be. The training has encouraged staff and suppliers already working in a low carbon way to continue and is ensuring that people who are unfamiliar feel confident in broaching a new way of working.	Kat lives and breathes carbon. She is the biggest advocate of promoting low carbon. Her knowledge around this complex topic is exceptional. Her partnerships across the organisation and with suppliers consistently and effectively promote the prioritisation and promotion of low carbon. There are still challenges ahead and cynics, however, with the continuous improvement of Eric this should improve with time and patience.	EPW, Sustainable Business Partner, Environment Agency
It has provided a single source of truth on whole life carbon and has moved us forward in that regard. However, it does require an extra activity at a point in time often when the design decisions have been made so the opportunity to make a change has been lost. Integrating the tool capability into business activities to use the intelligence to change our decisions to realise the full benefit of ERIC	Yes, it has. The name is widely used there is good familiarity with it.	Kat has a true passion for carbon reduction and engaging both internally and externally on the topic. She has been successful by improving knowledge within the EA and raising awareness of the work we have done to our supply chain and other associated groups.	KA, FCRM Manager, Environment Agency
The implementation of ERIC has definitely supported the prioritisation of low carbon, not only within FCRM but also a wider impact across the organisation. Before ERIC we had no accurate way of capturing and reporting the carbon cost of a project whether at planning or at final completion. This has been a game changer with people able to articulate carbon as a practical element of a project rather than a theoretical assumption. Also, the ability to model various options at the early stages of a project has meant the planning conversations have been able to add value around carbon considerations before final decisions are made	The wider promotion of ERIC and the training developed, including e-learning and face to face workshops has meant that a wider range of people understand and are able to utilise ERIC. Consistent repeated messages in various communications channels mean that ERIC is well known in and beyond the FCRM community including the supply chain. It has become a shorthand for carbon reduction within project teams including internal staff and supply chain.	Without Kat there would be no ERIC. She is the architect of the tool and is an excellent advocate of how the tool should be used to identify low carbon opportunities and reduce the levels of carbon throughout the whole life cycle of an asset. Kat is an acknowledged expert within the organisation and works tirelessly at all levels to make sure low carbon is promoted and prioritised in the organisation	LG, Sustainable Business Team Manager. Environment Agency
The carbon planning tool is vital to enabling FCRM to measure its carbon emissions. It is recognised as an industry leading tool for this purpose. Having the measures doesn't mean they 100% influence the solutions developed, but without them there is 0% influence. Where the tool is used early and meaningfully in the design stages, it has helped prioritise low carbon	Achieving a low carbon culture change needs a range of drivers including leadership, investment appraisal policy, industry leading practices/expertise and capabilities. The promotion and training for carbon planning has built an important level of expertise and capability in the organisation which we wouldn't have without it. This expertise is increasingly supporting a wider community of organisation roles such as project managers. It is the basis of a culture change that leadership and other drivers are now building on.	The role of Carbon Planning Manager has been instrumental in building the expertise, practices and tools we now have in the organisation. In this role Kat Ibbotson has ensured the standards are industry leading and that as an organisation we have the evidence of our carbon performance against targets. In his role Kat Ibbotson has significantly raised the profile of carbon and the need to reduce our emissions in FCRM and influenced a growing ambition to become a net-zero carbon organisation in the future.	Blank

blank	blank	Kat has shared her work with the Cross Whitehall Technical Group which has greatly enhanced the Carbon understanding and knowledge within the wider industry. The case studies are of particular relevance and will certainly help my organisation in decision making.	blank
The ERIC tool is fundamental to our approach to managing and reducing embodied carbon in our construction activities. Our KPI targets are based on the outputs of the tool and it helps drive carbon reduction and innovation in our construction activity	The guidance and training that accompanied the implementation of the ERIC tool has raised staff and supply chain awareness and given staff a tool to understand and promote carbon reducing options and approaches. It contributes to a culture of carbon efficiency in the Environment Agency and our supply chain partners	Katherine is a champion of carbon efficiency and has given clear and effective leadership to our agenda for carbon reduction. She has promoted the ERIOC tool to over 190 individuals and organisations outside of the Environment Agency. She is a highly regarded and much sought-after speaker at conferences and meetings where she promotes the agenda of carbon efficiency	JB, CEng MIMarEst, FIET Deputy Director Asset Performance and Engineering Flood & Coastal Risk Management

My experience has been that the Eric tools and associated carbon reports have provided the means for carbon reporting to be completed in a very systematic and standardised way, creating opportunities for project teams to measure and monitor their carbon progress. This allows the EA to monitor carbon reductions at a programme level and understand hotspots, therefore helping to prioritise low carbon design. The data collated in Eric has allowed more meaningful analysis around other low carbon programmes including carbon budgets to take place.	blank	Kat has very successfully supported low carbon in FCRM and the wider industry - she has been a great collaborator and communicator in bringing people from across the organisation and external together to share ideas, and has consistently pushed forwards to find and embed innovative solutions.	NF, Carbon Management Consultant, Mott MacDonald

APPENDIX L Research Ethics

RESEARCH ETHICS CHECKLIST
Form RE1

This checklist should be completed for <u>every</u> research project which involves human participants. It is used to identify whether a full application for ethics approval needs to be submitted.

Before completing this form, please refer to the University Code of Practice on Ethical Standards for Research Involving Human Participants. The principal investigator and, where the principal investigator is a student, the supervisor, is responsible for exercising appropriate professional judgment in this review.

This checklist must be completed before potential participants are approached to take part in any research.

Section I: Applicant Details

1.	Name of Researcher (applicant):	Katherine Ibbotson
2.	Status (please click to select):	PhD Student
3.	Email Address:	KM9bee@bolton.ac.uk
4a.	Contact Address:	University of Bolton
4b.	Telephone Number:	University of Bolton

Section II: Project Details

5.	Project Title:	Prioritising carbon reduction in UK public sector Flood and Coastal Risk Management

Section III: For Students Only:

6. Course title and module name and number where appropriate School/Centre:	PhD Engineering, Sports and Science
7. Supervisor's or module leader's name:	Peter Farrell
8. Email address:	P.Farrell@bolton.ac.uk
9. Telephone extension::	01294 903426

Declaration by Researcher (Please tick the appropriate boxes)

Yes	I have read the University's Code of Practice
Yes	The topic merits further research
Yes	I have the skills to carry out the research
Yes	The participant information sheet, if needed, is appropriate
Yes	The procedures for recruitment and obtaining informed consent, if needed, are appropriate
Yes	The research is exempt from further ethics review according to current University guidelines
Yes	Where relevant, I have read the ethical guidelines of the regulatory body that is relevant to my discipline and verify that the research adheres to these guidelines
Comments from Researcher, and/or from Supervisor if Researcher is Undergraduate or Taught Postgraduate student:	
N/A	

Section IV: Research Checklist

Please answer each question by ticking the appropriate box:

		YES	NO
1.	Will the study involve participants who are particularly vulnerable or who may be unable to give informed consent (e.g. children, people with learning disabilities, emotional difficulties, problems with understanding and/or communication, your own students)?	☐	X
2.	Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited (e.g. students at school, members of self-help group, residents of nursing home)?	☐	X
3.	Will deception be necessary, i.e. will participants take part without knowing the true purpose of the study or without their knowledge/consent at the time (e.g. covert observation of people in non-public places)?	☐	X
4.	Will the study involve discussion of topics which the participants may find sensitive (e.g. sexual activity, own drug use)?	☐	X
5.	Will drugs, placebos or other substances (e.g. food substances, alcohol, nicotine, vitamins) be administered to or ingested by participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?	☐	X
6.	Will blood or tissues samples be obtained from participants?	☐	X
7.	Will pain or more than mild discomfort be likely to result from the study?	☐	X
8.	Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?	☐	X
9.	Will the study involve prolonged or repetitive testing?	☐	X
10.	Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?	☐	X
11.	Will participants' right to withdraw from the study at any time be withheld or not made explicit?	☐	X

12.	Will participants' anonymity be compromised or their right to anonymity be withheld or information they give be identifiable as theirs?	☐	X
13.	Might permission for the study need to be sought from the researcher's or from participants' employer?	X	☐
14.	Will the study involve recruitment of patients or staff through the NHS?	☐	X

<u>If ALL items in the Declaration are ticked AND if you have answered NO to ALL questions in Section IV</u>, **send the completed and signed Form RE1 to your School/Centre Research Ethics Officer** for information. You may proceed with the research but should follow any subsequent guidance or requests from the School/Centre Research Ethics Officer or your supervisor/module leader where appropriate. Undergraduate and taught postgraduate students should retain a copy of this form and submit it with their research report or dissertation (bound in at the beginning). MPhil/PhD students should submit a copy to the Board of Studies for Research Degrees with their application for Registration (R1). **Work which is submitted without the appropriate ethics form will be returned unassessed.**

<u>If ANY of the items in the Declaration are not ticked AND / OR if you have answered YES to ANY of the questions in Section IV</u>, you will need to describe more fully in Section V of the form below how you plan to deal with the ethical issues raised by your research. **This does not mean that you cannot do the research, only that your proposal will need to be approved by the School/Centre Research Ethics Officer or School/Centre Research Ethics Committee or Sub-committee**. **When submitting the form as described in the above paragraph you should substitute the original Section V with the version authorized by the School/Centre Research Ethics officer.**

If you answered YES to ***question 14***, you will also have to submit an application to the appropriate external health authority ethics committee, after you have received approval from the School/Centre Research Ethics Officer/Committee and, where appropriate, the University Research Ethics Committee.

Section V: Addressing Ethical Problems

If you have answered YES to any of questions 1-12 please complete below and submit the form to your School/Centre Research Ethics Officer.

Project Title
Prioritising carbon reduction in UK public sector Flood and Coastal Risk Management

Principal Investigator/Researcher/Student
Katherine Ibbotson

Supervisor
Peter Farrell

Summary of issues and action to be taken to address the ethics problem(s)
Permission has been sought from Environment Agency, signed form is at the start of the thesis (organisational permission) dated 4th October 2018

Please note that it is your responsibility to follow the University's Code of Practice on Ethical Standards and any relevant academic or professional guidelines in the conduct of your study. **This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data**. Any significant change to the design or conduct of the research should be notified to the School/Centre Research Ethics Officer and may require a new application for ethics approval.

Signed: K Ibbotson ________________ Principal Investigator/Researcher

Approved: P Farrell by email____Supervisor or module leader (where appropriate)

Date: 4th October 2018

For use by School/Centre Research Ethics Officer:

- No ethical problems are raised by this proposed study - Retain this form on record

- Appropriate action taken to maintain ethical standards
- The research protocol should be revised to eliminate the ethical concerns or reduce them to an acceptable level, using the attached suggestions
- Please submit School/Centre Application for Ethics Approval (Form RE2(D))

Retain this form on record and return a copy of section V to Researcher

- Please submit University Application for Ethics Approval (Form RE2(U))

Signed: P Farrell by email__________

Date: 4th October 2018__________